

Puerto Rico's Hazard Risk Assessment

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University of Central Florida and Disaster Metrics, LLC.
Authored by: Dr. Christopher T. Emrich and Dr. Yao Zhou



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UCF



VMAP

VULNERABILITY MAPPING
ANALYSIS PLATFORM



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Introduction

Rationale

A complete risk assessment has four basic components, including: hazard identification; profiling of hazard events; inventory of assets; and an estimate of potential human and economic losses based on exposure and vulnerability of people, buildings, and infrastructure.¹ This report utilizes the Department of Homeland Security extended risk definition.² Here, risk is the potential for an adverse outcome assessed as a function of threats, vulnerabilities, and consequences associated with an incident, event, or occurrence. This report is partitioned into four (4) discrete sections strictly following DHS guidance: Threat Assessment, Vulnerability Assessment, Severity of Consequences Assessment, and the combination of these three resulting in Risk Assessment. A focus first on hazard identification and frequency analysis for all of Puerto Rico with an emphasis on utilizing the most appropriate data, methods, and analytic tools to meet rapid turn-around Community Development Block Grant – Mitigation (CDBG-MIT) timelines provides the basis from which sound planning and mitigation decisions can be made. This report is intended for CDBG-MIT risk assessment informational and planning purposes only. A rigorous geospatial approach and a deep understanding of hazards geography are utilized in the following analytics and associated results. Connecting empirically based hazard assessments with vulnerability, infrastructure at risk, and severity of consequences information provides a more holistic view of risks across Puerto Rico.

Methodology

Many hazard analytics processes in this assessment and spatial-analytic processes are adapted from previous risk assessment procedures in several state^{3,4} and regional⁵ local mitigation planning documents⁶. Several processes have been specifically altered to reflect Puerto Rico's location closer to the equator (hurricane hazard) and mountainous terrain (landslide hazard). Data specific to Puerto Rico for each hazard analyzed herein (Table 1) has been carefully reviewed to ensure data quality in several respects. These include spatial – does the data adequately reflect all of Puerto Rico?; temporal – does the data provide an appropriate timeframe for understanding current and future risks?; and numerical – is the data free from incomplete or inconsistent records?

¹ <https://www.fema.gov/hazard-identification-and-risk-assessment>

² https://www.dhs.gov/xlibrary/assets/dhs_risk_lexicon.pdf

³ <https://www.scemd.org/media/1391/sc-hazard-mitigation-plan-2018-update.pdf>

⁴ https://www.floridadisaster.org/globalassets/dem/mitigation/mitigate-fl--shmp/shmp-2018-full_final_approved.6.11.2018.pdf

⁵ <https://centralmidlands.org/freedocs/HMPforadoption-WithRevisions.pdf>

⁶ Puerto Rico Hazard Mitigation Plan - <https://recovery.pr/en/document-library>

Table 1: Hazards analyzed in this report, in order of priority of analysis⁷

Hazard	Data type	Period	Temporal/Spatial resolution	Methods	Dataset and/or Source*
Flood (100 year)	Polygon	-	Time independent	Modeled inundation of 100-year flood	Federal Emergency Management Agency
Hurricane	Point	1989-2018	6-hourly	Average times per year an area can expect to experience hurricane-force winds 34 kt	National Oceanic and Atmospheric Administration
Landslide	Grid	N/A	Various grid cell sizes	Average landslide susceptibility index in any given area	United States Geological Survey
Earthquake	Polygon	N/A	Time independent	Peak ground acceleration with a 2% probability of exceedance in 50 years	United States Geological Survey
Severe Storm	Polygon	2002-2019	Yearly	Average number of times per year an area can expect to be under a severe thunderstorm warning	Iowa State University's Environmental Mesonet
Storm Surge	Grid	N/A	Time independent/30 m	Modeled inundation of storm surge from a Category-1 hurricane	National Oceanic and Atmospheric Administration
Drought	Polygon	2000-2019	Weekly	Average number of weeks in drought per year	United States Drought Monitor
Wind	Point	1989-2018	Daily	Average number of days per year with winds above 30 knots	National Oceanic and Atmospheric Administration
Fog	Point	1989-2018	Daily	Average number of fog days per year using weather station interpolation	National Oceanic and Atmospheric Administration

⁷ Priority of analysis determined by Puerto Rico Hazard Mitigation Plan - <https://recovery.pr/en/document-library>

Hail	Point/Line	1955-2018	Yearly	Average number of reported hail events per year	National Oceanic and Atmospheric Administration
High Temperature	Point	1989-2018	Daily	Average number of days where the daily maximum is above 100 °F	National Oceanic and Atmospheric Administration
Lightning	Point	2009-2018	Daily	Average number of cloud-to-ground lightning flashes per year	World Wide Lightning Detection Network
Tornado	Polygon	2002-2019	Yearly	Average number of times per year an area can expect to be under a tornado warning	Iowa State University's Environmental Mesonet
Wildfires	Polygon	2003- 2011	Yearly	Average number of wildfires	USDA Caribbean Climate Hub
Human Hazards	Polygon	1970 - Present	Daily	Average annual number of terrorist events of chemical transportation spill	Global Terrorism Database and Pipeline and Hazardous Materials Safety Administration
Liquefaction	Polygon	N/A	Time independent	Liquefaction susceptibility index	Universidad Metropolitana (2002(
Sea Level Rise	Polygon	N/A	Time independent	Sea Level Rise – Feet (1, 4, 10) above Mean Higher High Water (MHHW) level.	National Oceanic and Atmospheric Administration
Tsunami	Polygon	N/A	Time independent		Puerto Rico Seismic Network Tsunami Program

A ½-square-mile hexagonal grid is used in this assessment because it provides the best coverage for small spatial areas, such as Cantano Municipio, while providing an ability to visualize spatial differences across the island as a whole (Figure 1). Summarizing underlying spatial data to the ½-square-mile grid cell provides a specific set of information that will be different than using a different sized grid cell. Different grid sizes will yield different results.

Hexagonal grids represent a simplified method to display complex geospatial information⁸ in an approachable way⁹. Using regular spatial bins (hexagons) serves three primary goals: First, it simplifies data sets and aids in visual communication of complex data. If done correctly, visual binning can enable readers to make reasonable count or density estimates that would otherwise be impossible because of the complexity of underlying data. Second, spatial binning shows a smooth surface of aggregated values across larger areas. Finally, a standardized regular gridded framework, such as the hexagonal grids used here enables analysis and evaluation within and between datasets that would normally be difficult (or impossible) to visually, statistically, or spatially compare.

⁸ <https://www.tableau.com/about/blog/2017/11/data-map-discovery-78603>

⁹

https://www.researchgate.net/publication/303290602_Shapes_on_a_plane_evaluating_the_impact_of_projection_distortion_on_spatial_binning

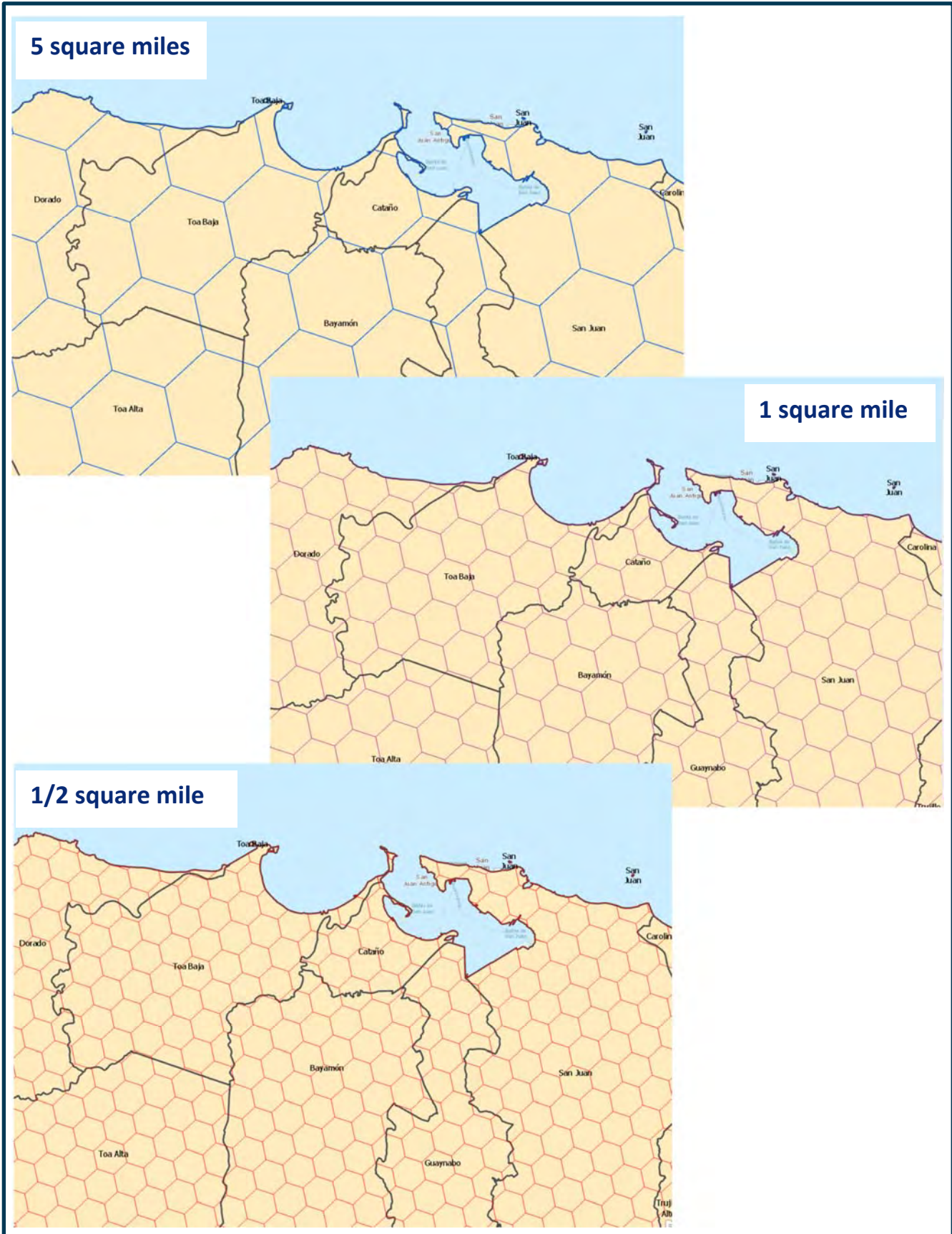


Figure 1: Comparison of Hexagonal Grids for Puerto Rico

Report Format

The analysis and associated outputs of this report are not intended to replace more detailed, multi-year risk assessment process such as updating FEMA required risk assessments and mitigation plans. A geospatial analytics focus on hazard geographies forms the basis of the current assessment. As such, each hazard section provides the following standardized information:

1. Overview of Hazard. Where applicable, background material on hazards is adapted from Puerto Rico's current Hazard Mitigation Plan (HMP)¹⁰. A brief background is provided if a hazard has not been cataloged in Puerto Rico's HMP.
2. Data and Methods. General descriptions of data and methods are provided for reference.
3. Hazard Frequency Analysis Results. An overview of hazard frequency across Puerto Rico including
 - a. Maps of hazard zones. Hazard categories for each hazard type are provided showing frequency of occurrence or other hazard zone/category information for each municipio.
 - b. Tables of land area impacted. Three distinct tables are provided each showing results from slightly different perspectives.
 - i. Land area in each municipio/hazard zone/category combination.
 - ii. Percentage of municipio land area in each municipio/hazard zone/category combination
 - iii. Percentage of total island land area in each municipio/hazard zone/category combination
 - iv. Standardized hazard score for each municipio. Utilizing the hexagonal grid enables a relative comparison of hazard zones for each municipio. A score for each hazard category (1 - Low to 5 - High) was created by first calculating the percentage of total island land area in each "zone" in comparison to total island land area.
 - v.
 - vi.
 - vii.
 - viii. Table 2 provides an example (based on severe storm hazard) showing that Adjuntas Municipio has .88% of the total island-wide land area in the 'Low' severe storm category, another 1.01% in 'Medium Low', .05% in 'Medium' in no land in 'Medium High' or 'High' categories.

¹⁰ Puerto Rico Hazard Mitigation Plan - <https://recovery.pr/en/document-library>

Table 2: Example of Hazard Scoring Step 1, Calculating Percentage Area for Each Category

Municipio	Severe Storm Percentage of Total (Island) Land Area				
	Low	Medium Low	Medium	Medium High	High
Adjuntas	0.88%	1.01%	0.05%	0.00%	0.00%
Aguada	0.00%	0.00%	0.83%	0.07%	0.00%
Aguadilla	0.00%	0.00%	1.05%	0.00%	0.00%
Aguas Buenas	0.00%	0.25%	0.62%	0.00%	0.00%
Aibonito	0.73%	0.17%	0.01%	0.00%	0.00%
Anasco	0.00%	0.03%	0.43%	0.42%	0.26%
Arecibo	0.25%	1.74%	1.68%	0.00%	0.00%
Arroyo	0.00%	0.07%	0.37%	0.00%	0.00%
Barceloneta	0.00%	0.50%	0.04%	0.00%	0.00%

Each of these municipio/hazard category combinations is then “normalized” to a 0-1 scale using a min/max scaling technique. In this approach, the data is scaled to a fixed range of 0 to 1. Min-Max scaling is accomplished using the following equation:

$$X_{sc} = \frac{X - \text{Min } X}{\text{Max } X - \text{Min } X}$$

Resulting values represent a minimum (0) to a maximum (1) score for each hazard zone category and each municipio (Table 5). There are several ways to represent how hazardous a particular area is. One is called straight line in which we simply assign a number to the level of hazard without considering any other factors, or weighting, that number. Another is called interval (1-5) multiplicative weighting. The problem with these two systems is that, in places where there is a lot of geographic area with “Medium High” hazard risk, it will get a higher number than someplace with a smaller geographic area but a higher hazard risk. This could confuse results and the actions that follow. Instead, we decided to use logarithmic weighting which codifies an increased threat in higher hazard areas over lower hazard areas. Values are converted to a log-multiplied score where ‘Low’ score is multiplied by 1, ‘Medium Low’ score is multiplied by 10, ‘Medium’ score multiplied by 100, ‘Medium High’ score multiplied by 1,000, and ‘High’ score by 10,000. Then, the scores are rescaled to 0-1 using the min/max scaling procedures used above.

Table 3: Example Of Hazard Scoring Step 2, Calculating Min/Max Values for Each Category/Municipio

Municipio	Min/Mx of Severe Storm Percentage of Total (Island) Land Area					Log multiplier score	Severe Storms Score
	Low	Medium Low	Medium	Medium High	High		
Adjuntas	0.39	0.58	0.02	0.00	0.00	22.62	0.0002
Aguada	0.00	0.00	0.26	0.09	0.00	1172.07	0.0111
Aguadilla	0.00	0.00	0.33	0.01	0.00	390.16	0.0037
Aguas Buenas	0.00	0.14	0.20	0.00	0.00	197.32	0.0019
Aibonito	0.32	0.10	0.00	0.00	0.00	4.13	0.0000
Anasco	0.00	0.02	0.14	0.57	0.18	23987.60	0.2268
Arecibo	0.11	1.00	0.53	0.00	0.00	542.33	0.0051
Arroyo	0.00	0.04	0.12	0.00	0.00	117.30	0.0011
Barceloneta	0.00	0.29	0.01	0.00	0.00	14.92	0.0001

Hazard Threat Analysis and Findings

100-year Flooding

Hazard Overview

Flooding is the most frequent and costly natural hazard in the United States. Floods are generally the result of excessive precipitation, and can be classified under two categories: flash floods, the product of heavy localized precipitation in short time period over a given location; and general floods, caused by precipitation over a longer time period and over a given river basin. The severity of a flooding event is determined by a combination of stream and river basin topography and physiography, precipitation and weather patterns, recent soil moisture conditions and the degree of vegetative clearing. Flash flooding events usually occur within minutes or hours of heavy amounts of rainfall, from a dam or levee failure, or from a sudden release of water held by an ice jam. Most flash flooding is caused by slow-moving thunderstorms in a local area or by heavy rains associated with hurricanes and tropical storms. Although flash flooding occurs often along mountain streams, it is also common in urbanized areas where much of the ground is covered by impervious surfaces. General floods are usually longer-term events and may last for several days. The primary types of general flooding include riverine flooding, coastal flooding and urban flooding. Riverine flooding is a function of excessive precipitation levels and water runoff volumes within the watershed of a stream or river. Coastal flooding is typically a result of storm surge, wind-driven waves, and heavy rainfall produced by hurricanes, tropical storms, and other large coastal storms. Urban flooding occurs where man-made development has obstructed the natural flow of water and/or decreased the ability of natural groundcover to absorb and retain surface water runoff.

Data and Methods

The Federal Emergency Management Agency (FEMA) provides a national flood hazard dataset for the US through an online Map Service Center (MSC). Accordingly, we downloaded for the entire US the Special Flood Hazard Area (SFHA) dataset, which represents flood hazards with a 0.01 probability of occurrence in any given year, commonly referred to as a 100-year flood or the 1% annual chance of flooding. Though additional flood zones exist for many locations in the US, depicting the 0.002 chance (500-year) of flooding or areas that may experience high velocity floodwater flows, we utilize only the 100-year SFHA data in our composite hazard analysis. In the case of Puerto Rico, Preliminary 100-year Flood Zones, provided by the Puerto Rico Planning Board, were spatially intersected with Puerto Rico's 0.5-mile hexagonal grid to produce a spatial representation of flood hazard across the island.

Hazard Frequency Analysis Results

Flood hazard potential is present in every municipio, but is significantly more pronounced along the north central, northeastern, eastern, south central, south east, and western municipios (Figure 2). This map categorizes each ½ mile hex grid based on the amount of land area it has inside the FEMA Preliminary 100-Year Flood Zone using equal interval classification. Unlike simply using the flood zone perimeter, this map allows for areal comparison across the island. The northwestern municipios appear to have relatively less flood hazard potential than most of the other enumeration units across the island. Additionally, inland municipios such as Caguas, Gurabo, and Juncos have more areas at flood risk than most other inland neighbors. Analytic results populated into municipio level tables provide a higher level of information than available from an island wide map. Table 4 shows the total land area in square miles in each flood category, Table 5 shows the percent of each municipios land area in each category, and Table 6 shows the percent of total Puerto Rico land area in each category by municipio. Finally, Table 7 provides a rank order breakdown of land area in 100-year flood hazard areas by municipio.

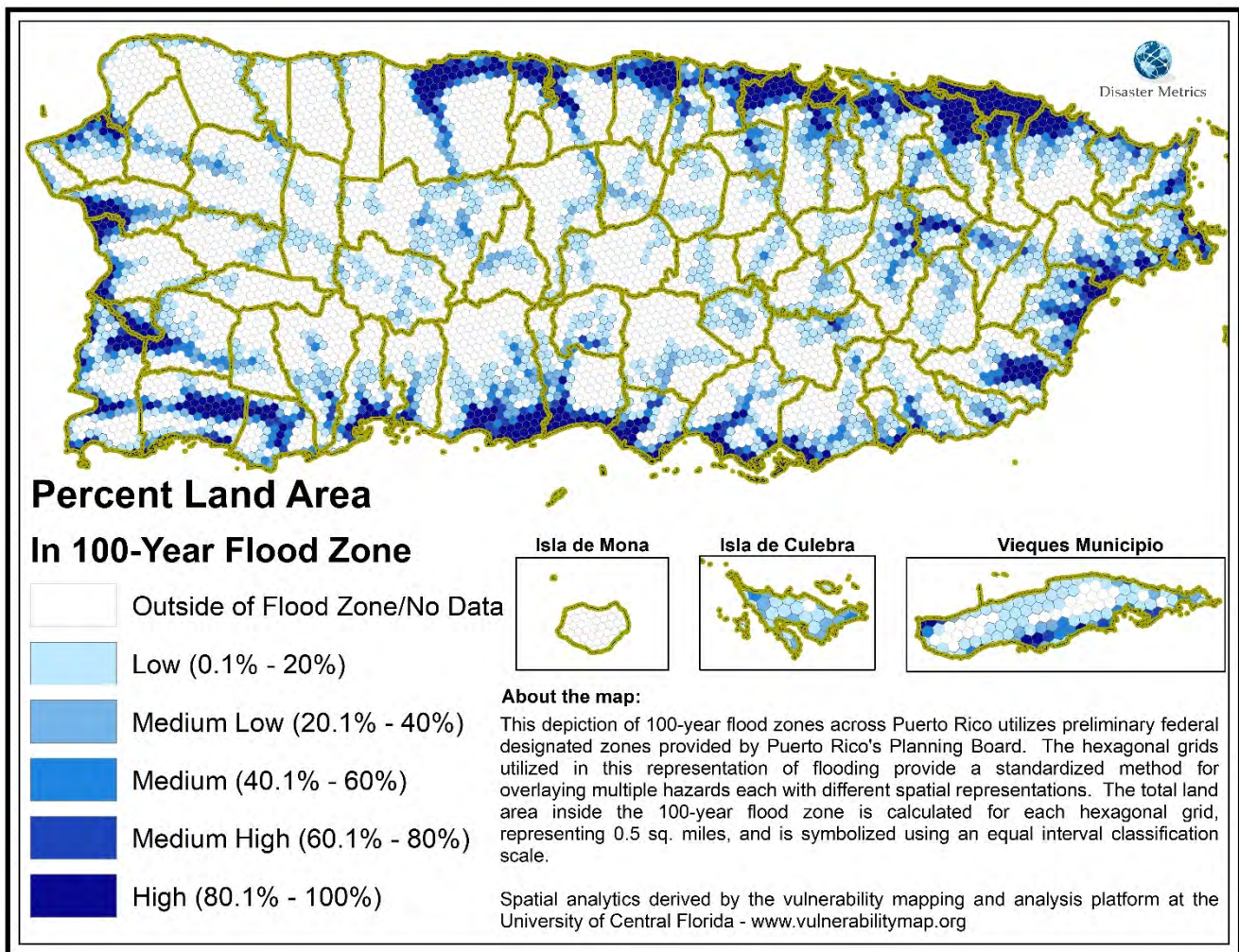


Figure 2: 100-Year Flood Zone Hazard Areas

Table 4: 100-Year Flooding by Municipio and Areal Extent

Municipio	Hex Grid Area in 100-Year Flood Zones (Sq. miles)					
	None (0%)	Low (0.1% - 20%)	Medium Low (20.1% - 40%)	Medium (40.1% - 60%)	Medium High (60.1% - 80%)	High (>80%)
Adjuntas	43.52	21.88	1.70			
Aguada	12.38	7.23	2.34	3.39	1.35	4.23
Aguadilla	28.52	4.42	1.29	0.63	0.79	0.96
Aguas Buenas	20.42	9.50	0.17			
Aibonito	14.34	16.00	1.00			
Anasco	16.70	8.70	4.29	2.00	1.42	6.46
Arecibo	85.47	8.07	5.94	5.68	6.39	15.43
Arroyo	6.24	3.79	1.50	1.42	0.48	1.61
Barceloneta	8.43	1.51	0.07	0.96	2.84	4.95
Barranquitas	22.73	11.56				
Bayamon	21.33	12.92	3.56	2.99	0.61	3.10
Cabo Rojo	25.99	17.71	7.35	5.55	3.97	12.54
Caguas	25.71	21.99	4.22	3.58	2.58	0.99
Camuy	40.88	4.41	0.48	0.22	0.29	0.08
Canovanas	16.97	6.13	2.88	1.82	1.00	4.21
Cantano	11.97	12.24	0.46	2.18	3.45	17.01
Carolina						5.08
Cayey	35.59	11.75	3.00	0.67	0.50	0.45
Ceiba	7.38	9.47	3.09	3.24	1.65	5.54
Ciales	48.62	15.13	2.00	0.96		
Cidra	20.26	12.49	3.32	0.33		0.05
Coamo	59.95	15.01	3.00	0.07		
Comerio	18.96	8.57	0.50	0.50		
Corozal	27.75	14.83				
Culebra	0.50	7.18	4.80	0.75	0.05	0.03
Dorado	6.48	3.31	2.00	2.52	2.60	6.52
Fajardo	11.65	8.05	2.71	4.01	2.45	1.65
Florida	15.22					
Guanica	13.53	7.59	4.12	5.34	3.43	5.01
Guayama	32.56	18.29	5.00	2.84	1.00	6.18
Guayanilla	21.14	10.94	2.37	2.00	2.09	4.46
Guaynabo	12.29	9.95	3.39	0.51	0.39	1.24
Gurabo	12.71	7.00	2.65	1.94	2.01	2.01
Hatillo	36.13	4.05	0.90	0.22	0.39	0.15
Hormigueros	2.21	1.67	1.13	0.91	0.69	4.74
Humacao	6.91	16.27	5.95	4.50	2.84	8.64
Isabela	44.37	7.78	2.30	0.72		0.25
Jayuya	34.69	7.34	2.50			

Municipio	Hex Grid Area in 100-Year Flood Zones (Sq. miles)					
	None (0%)	Low (0.1% - 20%)	Medium Low (20.1% - 40%)	Medium (40.1% - 60%)	Medium High (60.1% - 80%)	High (>80%)
Juana Diaz	30.79	11.28	2.98	4.21	2.00	9.47
Juncos	12.28	8.01	4.33	0.99	1.00	
Lajas	23.80	13.31	3.08	3.91	3.90	13.36
Lares	45.86	15.16	0.62			
Las Marias	33.11	11.84	1.56			
Las Piedras	23.68	8.82	0.90		0.50	
Loiza		0.44	0.19	0.23	1.10	18.57
Luquillo	8.10	10.17	3.73	1.52	1.17	1.18
Manati	26.90	5.09	5.13	1.18	2.10	6.43
Maricao	31.55	5.08				
Maunabo	8.67	8.55	1.98		1.00	0.88
Mayaguez	55.80	8.86	2.06	2.01	1.89	7.35
Moca	39.45	6.44	3.20	0.92	0.36	
Morovis	25.56	11.28	2.04	0.04		
Naguabo	19.00	15.03	6.30	2.27	3.89	5.39
Naranjito	19.68	6.37	1.69			
Orocovis	48.10	14.89	0.78			
Patillas	28.36	12.22	2.15	1.47	2.22	0.80
Penuelas	28.61	9.72	2.00	0.98	1.46	1.98
Ponce	57.01	27.01	5.98	6.47	4.00	16.51
Quebradillas	15.55	6.14	0.53	0.63	0.28	
Rio Grande	8.71	3.22	1.89	0.03	0.33	0.21
Rincon	29.89	14.39	3.21	1.98	1.82	9.52
Sabana Grande	27.41	6.62	1.26	0.55		
Salinas	35.67	14.44	4.50	4.17	2.50	8.78
San German	29.99	11.86	4.09	4.54	1.16	2.87
San Juan	19.81	13.58	3.00	4.03	3.79	5.32
San Lorenzo	33.18	16.63	3.40			
San Sebastian	50.98	13.76	4.82	1.44	0.22	
Santa Isabel	11.29	8.29	2.50	1.61	3.04	7.85
Toa Alta	11.16	9.04	4.15	2.22	0.50	0.50
Toa Baja	4.47	2.03	1.55	1.16	0.62	13.97
Trujillo Alto	10.02	7.65	1.79	1.00	0.92	
Utua	75.38	32.16	6.02	1.50		
Vega Alta	11.50	7.87	3.09	2.28	2.05	0.95
Vega Baja	20.63	8.58	0.99	4.57	2.97	8.90
Vieques	14.00	25.61	4.54	3.91	2.63	2.50
Villalba	22.82	10.97	1.63	0.61	1.00	
Yabucoa	30.99	9.91	1.43	2.00	3.99	7.09
Yauco	45.88	15.64	3.68	2.00	1.11	0.52

Municipio	Hex Grid Area in 100-Year Flood Zones (Sq. miles)					
	None (0%)	Low (0.1% - 20%)	Medium Low (20.1% - 40%)	Medium (40.1% - 60%)	Medium High (60.1% - 80%)	High (>80%)
Grand Total	1946.16	812.67	200.74	128.84	100.77	274.44

Table 5: Percent of (Municipio) Hexagonal Area by 100-Year Flooding per Municipio

Municipio	100-Year Flood Zone Percent Area by Total (Municipio) Land Area					
	None (0%)	Low (0.1% - 20%)	Medium Low (20.1% - 40%)	Medium (40.1% - 60%)	Medium High (60.1% - 80%)	High (>80%)
Adjuntas	64.86%	32.61%	2.53%	0.00%	0.00%	0.00%
Aguada	40.04%	23.37%	7.56%	10.97%	4.37%	13.69%
Aguadilla	77.90%	12.06%	3.53%	1.72%	2.17%	2.61%
Aguas Buenas	67.86%	31.56%	0.57%	0.00%	0.00%	0.00%
Aibonito	45.75%	51.05%	3.20%	0.00%	0.00%	0.00%
Anasco	42.21%	22.00%	10.84%	5.06%	3.59%	16.32%
Arecibo	67.32%	6.35%	4.67%	4.47%	5.03%	12.15%
Arroyo	41.46%	25.18%	10.00%	9.45%	3.19%	10.72%
Barceloneta	44.94%	8.02%	0.36%	5.13%	15.17%	26.37%
Barranquitas	66.29%	33.71%	0.00%	0.00%	0.00%	0.00%
Bayamon	47.92%	29.02%	8.00%	6.72%	1.38%	6.97%
Cabo Rojo	35.54%	24.23%	10.06%	7.59%	5.44%	17.15%
Caguas	43.53%	37.23%	7.14%	6.06%	4.36%	1.68%
Camuy	88.16%	9.52%	1.04%	0.48%	0.63%	0.17%
Canovanas	51.43%	18.56%	8.71%	5.52%	3.03%	12.74%
Cantano	25.30%	25.87%	0.98%	4.60%	7.29%	35.96%
Carolina	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
Cayey	68.49%	22.62%	5.77%	1.29%	0.96%	0.87%
Ceiba	24.30%	31.17%	10.18%	10.66%	5.45%	18.25%
Ciales	72.89%	22.68%	3.00%	1.43%	0.00%	0.00%
Cidra	55.59%	34.26%	9.12%	0.91%	0.00%	0.13%
Coamo	76.83%	19.24%	3.84%	0.09%	0.00%	0.00%
Comerio	66.46%	30.03%	1.75%	1.75%	0.00%	0.00%
Corozal	65.16%	34.84%	0.00%	0.00%	0.00%	0.00%
Culebra	3.76%	53.98%	36.06%	5.63%	0.37%	0.20%
Dorado	27.65%	14.12%	8.53%	10.74%	11.09%	27.86%
Fajardo	38.17%	26.39%	8.87%	13.13%	8.04%	5.39%
Florida	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Guanica	34.68%	19.45%	10.55%	13.68%	8.80%	12.83%
Guayama	49.44%	27.76%	7.58%	4.31%	1.52%	9.38%
Guayanilla	49.18%	25.44%	5.51%	4.64%	4.86%	10.36%
Guaynabo	44.28%	35.82%	12.20%	1.83%	1.39%	4.48%

Municipio	100-Year Flood Zone Percent Area by Total (Municipio) Land Area					
	None (0%)	Low (0.1% - 20%)	Medium Low (20.1% - 40%)	Medium (40.1% - 60%)	Medium High (60.1% - 80%)	High (>80%)
Gurabo	44.90%	24.72%	9.36%	6.83%	7.09%	7.10%
Hatillo	86.36%	9.68%	2.14%	0.52%	0.94%	0.36%
Hormigueros	19.48%	14.68%	9.99%	8.01%	6.10%	41.74%
Humacao	15.32%	36.08%	13.19%	9.98%	6.29%	19.15%
Isabela	80.08%	14.04%	4.14%	1.29%	0.00%	0.44%
Jayuya	77.90%	16.49%	5.61%	0.00%	0.00%	0.00%
Juana Diaz	50.70%	18.57%	4.90%	6.94%	3.29%	15.59%
Juncos	46.14%	30.11%	16.28%	3.70%	3.76%	0.00%
Lajas	38.78%	21.70%	5.02%	6.38%	6.35%	21.77%
Lares	74.41%	24.59%	1.00%	0.00%	0.00%	0.00%
Las Marias	71.19%	25.46%	3.35%	0.00%	0.00%	0.00%
Las Piedras	69.86%	26.02%	2.65%	0.00%	1.47%	0.00%
Loiza	0.00%	2.16%	0.93%	1.12%	5.36%	90.42%
Luquillo	31.32%	39.33%	14.42%	5.87%	4.51%	4.54%
Manati	57.44%	10.87%	10.96%	2.51%	4.48%	13.73%
Maricao	86.14%	13.86%	0.00%	0.00%	0.00%	0.00%
Maunabo	41.10%	40.57%	9.41%	0.00%	4.74%	4.18%
Mayaguez	71.57%	11.36%	2.65%	2.58%	2.42%	9.43%
Moca	78.33%	12.78%	6.36%	1.82%	0.71%	0.00%
Morovis	65.67%	28.98%	5.24%	0.12%	0.00%	0.00%
Naguabo	36.63%	28.97%	12.14%	4.38%	7.50%	10.39%
Naranjito	70.92%	22.97%	6.11%	0.00%	0.00%	0.00%
Orocovis	75.43%	23.35%	1.22%	0.00%	0.00%	0.00%
Patillas	60.06%	25.88%	4.54%	3.12%	4.70%	1.69%
Penuelas	63.91%	21.72%	4.47%	2.19%	3.27%	4.43%
Ponce	48.73%	23.09%	5.12%	5.53%	3.42%	14.11%
Quebradillas	67.20%	26.56%	2.31%	2.72%	1.22%	0.00%
Rio Grande	60.56%	22.38%	13.11%	0.24%	2.27%	1.44%
Rincon	49.15%	23.66%	5.28%	3.26%	3.00%	15.65%
Sabana Grande	76.49%	18.47%	3.51%	1.53%	0.00%	0.00%
Salinas	50.91%	20.61%	6.42%	5.95%	3.57%	12.54%
San German	55.02%	21.75%	7.50%	8.33%	2.12%	5.27%
San Juan	40.00%	27.43%	6.06%	8.13%	7.66%	10.73%
San Lorenzo	62.36%	31.25%	6.39%	0.00%	0.00%	0.00%
San Sebastian	71.58%	19.32%	6.77%	2.02%	0.31%	0.00%
Santa Isabel	32.65%	23.97%	7.23%	4.64%	8.80%	22.71%
Toa Alta	40.48%	32.80%	15.05%	8.05%	1.81%	1.81%
Toa Baja	18.79%	8.53%	6.51%	4.86%	2.61%	58.70%
Trujillo Alto	46.88%	35.78%	8.37%	4.68%	4.29%	0.00%
Utua	65.51%	27.95%	5.23%	1.30%	0.00%	0.00%

Municipio	100-Year Flood Zone Percent Area by Total (Municipio) Land Area					
	None (0%)	Low (0.1% - 20%)	Medium Low (20.1% - 40%)	Medium (40.1% - 60%)	Medium High (60.1% - 80%)	High (>80%)
Vega Alta	41.45%	28.37%	11.15%	8.23%	7.38%	3.41%
Vega Baja	44.23%	18.40%	2.13%	9.79%	6.37%	19.07%
Vieques	26.32%	48.15%	8.53%	7.36%	4.94%	4.70%
Villalba	61.63%	29.62%	4.41%	1.64%	2.70%	0.00%
Yabucoa	55.94%	17.88%	2.58%	3.61%	7.19%	12.80%
Yauco	66.67%	22.72%	5.34%	2.91%	1.61%	0.75%

Table 6: Percent of (Island) Hexagonal Area by 100-Year Flooding per Municipio

Municipio	100-Year Flood Zone Percent Area by Total (Island) Land Area					
	None (0%)	Low (0.1% - 20%)	Medium Low (20.1% - 40%)	Medium (40.1% - 60%)	Medium High (60.1% - 80%)	High (>80%)
Adjuntas	2.24%	2.69%	0.85%	0.00%	0.00%	0.00%
Aguada	0.64%	0.89%	1.16%	2.63%	1.34%	1.54%
Aguadilla	1.47%	0.54%	0.64%	0.49%	0.79%	0.35%
Aguas Buenas	1.05%	1.17%	0.09%	0.00%	0.00%	0.00%
Aibonito	0.74%	1.97%	0.50%	0.00%	0.00%	0.00%
Anasco	0.86%	1.07%	2.14%	1.55%	1.41%	2.35%
Arecibo	4.39%	0.99%	2.96%	4.41%	6.34%	5.62%
Arroyo	0.32%	0.47%	0.75%	1.10%	0.48%	0.59%
Barceloneta	0.43%	0.19%	0.03%	0.75%	2.82%	1.80%
Barranquitas	1.17%	1.42%	0.00%	0.00%	0.00%	0.00%
Bayamon	1.10%	1.59%	1.77%	2.32%	0.61%	1.13%
Cabo Rojo	1.34%	2.18%	3.66%	4.30%	3.94%	4.57%
Caguas	1.32%	2.71%	2.10%	2.78%	2.56%	0.36%
Camuy	2.10%	0.54%	0.24%	0.17%	0.29%	0.03%
Canovanas	0.87%	0.75%	1.43%	1.42%	0.99%	1.53%
Cantano	0.61%	1.51%	0.23%	1.69%	3.42%	6.20%
Carolina	0.00%	0.00%	0.00%	0.00%	0.00%	1.85%
Cayey	1.83%	1.45%	1.49%	0.52%	0.50%	0.16%
Ceiba	0.38%	1.16%	1.54%	2.51%	1.64%	2.02%
Ciales	2.50%	1.86%	1.00%	0.74%	0.00%	0.00%
Cidra	1.04%	1.54%	1.66%	0.26%	0.00%	0.02%
Coamo	3.08%	1.85%	1.49%	0.05%	0.00%	0.00%
Comerio	0.97%	1.05%	0.25%	0.39%	0.00%	0.00%
Corozal	1.43%	1.83%	0.00%	0.00%	0.00%	0.00%
Culebra	0.03%	0.88%	2.39%	0.58%	0.05%	0.01%
Dorado	0.33%	0.41%	1.00%	1.95%	2.58%	2.38%
Fajardo	0.60%	0.99%	1.35%	3.11%	2.43%	0.60%
Florida	0.78%	0.00%	0.00%	0.00%	0.00%	0.00%

Municipio	100-Year Flood Zone Percent Area by Total (Island) Land Area					
	None (0%)	Low (0.1% - 20%)	Medium Low (20.1% - 40%)	Medium (40.1% - 60%)	Medium High (60.1% - 80%)	High (>80%)
Guanica	0.70%	0.93%	2.05%	4.14%	3.41%	1.82%
Guayama	1.67%	2.25%	2.49%	2.20%	0.99%	2.25%
Guayanilla	1.09%	1.35%	1.18%	1.55%	2.07%	1.62%
Guaynabo	0.63%	1.22%	1.69%	0.40%	0.38%	0.45%
Gurabo	0.65%	0.86%	1.32%	1.50%	1.99%	0.73%
Hatillo	1.86%	0.50%	0.45%	0.17%	0.39%	0.06%
Hormigueros	0.11%	0.20%	0.56%	0.71%	0.69%	1.73%
Humacao	0.36%	2.00%	2.96%	3.49%	2.81%	3.15%
Isabela	2.28%	0.96%	1.14%	0.56%	0.00%	0.09%
Jayuya	1.78%	0.90%	1.25%	0.00%	0.00%	0.00%
Juana Diaz	1.58%	1.39%	1.48%	3.27%	1.98%	3.45%
Juncos	0.63%	0.99%	2.16%	0.76%	0.99%	0.00%
Lajas	1.22%	1.64%	1.54%	3.04%	3.87%	4.87%
Lares	2.36%	1.87%	0.31%	0.00%	0.00%	0.00%
Las Marias	1.70%	1.46%	0.78%	0.00%	0.00%	0.00%
Las Piedras	1.22%	1.09%	0.45%	0.00%	0.49%	0.00%
Loiza	0.00%	0.05%	0.10%	0.18%	1.09%	6.77%
Luquillo	0.42%	1.25%	1.86%	1.18%	1.16%	0.43%
Manati	1.38%	0.63%	2.56%	0.91%	2.08%	2.34%
Maricao	1.62%	0.62%	0.00%	0.00%	0.00%	0.00%
Maunabo	0.45%	1.05%	0.99%	0.00%	0.99%	0.32%
Mayaguez	2.87%	1.09%	1.03%	1.56%	1.87%	2.68%
Moca	2.03%	0.79%	1.60%	0.71%	0.35%	0.00%
Morovis	1.31%	1.39%	1.02%	0.03%	0.00%	0.00%
Naguabo	0.98%	1.85%	3.14%	1.76%	3.86%	1.96%
Naranjito	1.01%	0.78%	0.84%	0.00%	0.00%	0.00%
Orocovis	2.47%	1.83%	0.39%	0.00%	0.00%	0.00%
Patillas	1.46%	1.50%	1.07%	1.14%	2.20%	0.29%
Penuelas	1.47%	1.20%	1.00%	0.76%	1.45%	0.72%
Ponce	2.93%	3.32%	2.98%	5.02%	3.97%	6.01%
Quebradillas	0.80%	0.76%	0.27%	0.49%	0.28%	0.00%
Rjo Grande	0.45%	0.40%	0.94%	0.03%	0.32%	0.08%
Rincon	1.54%	1.77%	1.60%	1.54%	1.81%	3.47%
Sabana Grande	1.41%	0.81%	0.63%	0.43%	0.00%	0.00%
Salinas	1.83%	1.78%	2.24%	3.23%	2.48%	3.20%
San German	1.54%	1.46%	2.04%	3.52%	1.15%	1.05%
San Juan	1.02%	1.67%	1.49%	3.13%	3.76%	1.94%
San Lorenzo	1.70%	2.05%	1.69%	0.00%	0.00%	0.00%
San Sebastian	2.62%	1.69%	2.40%	1.11%	0.22%	0.00%
Santa Isabel	0.58%	1.02%	1.25%	1.25%	3.02%	2.86%

Municipio	100-Year Flood Zone Percent Area by Total (Island) Land Area					
	None (0%)	Low (0.1% - 20%)	Medium Low (20.1% - 40%)	Medium (40.1% - 60%)	Medium High (60.1% - 80%)	High (>80%)
Toa Alta	0.57%	1.11%	2.07%	1.72%	0.50%	0.18%
Toa Baja	0.23%	0.25%	0.77%	0.90%	0.62%	5.09%
Trujillo Alto	0.52%	0.94%	0.89%	0.78%	0.91%	0.00%
Utua	3.87%	3.96%	3.00%	1.16%	0.00%	0.00%
Vega Alta	0.59%	0.97%	1.54%	1.77%	2.03%	0.35%
Vega Baja	1.06%	1.06%	0.50%	3.55%	2.95%	3.24%
Vieques	0.72%	3.15%	2.26%	3.04%	2.61%	0.91%
Villalba	1.17%	1.35%	0.81%	0.47%	0.99%	0.00%
Yabucoa	1.59%	1.22%	0.71%	1.55%	3.95%	2.58%
Yauco	2.36%	1.92%	1.83%	1.55%	1.10%	0.19%

Table 7: 100-Year Flood Hazard Scores and Ranks by Municipio

Municipio	100-Year Flooding Hazard Score (Log Multiplied)		
	Total Score	Standardized Score (0-1)	Rank of Score (1 – 78)
Loiza	10,176.1003	1	1
Carolina	9,734.7295	0.9566	2
Ponce	9,624.1830	0.9458	3
Arecibo	9,405.5651	0.9243	4
Lajas	7,869.1423	0.7733	5
Toa Baja	7,642.7714	0.7511	6
Cabo Rojo	7,471.8646	0.7343	7
Juana Diaz	5,480.9566	0.5386	8
Rio Grande	5,445.9575	0.5352	9
Vega Baja	5,328.7416	0.5237	10
Salinas	5,192.3116	0.5102	11
Humacao	5,173.5534	0.5084	12
Santa Isabel	4,732.4740	0.4651	13
Yabucoa	4,476.4757	0.4399	14
Mayaguez	4,288.0298	0.4214	15
Dorado	3,961.5483	0.3893	16
Manati	3,816.6956	0.3751	17
Anasco	3,735.8522	0.3671	18
Naguabo	3,556.3199	0.3495	19
Guayama	3,536.8567	0.3476	20
San Juan	3,522.9634	0.3462	21
Guanica	3,321.9363	0.3264	22
Ceiba	3,298.0640	0.3241	23
Barceloneta	3,124.5844	0.3071	24

Guayanilla	2,761.0856	0.2713	25
Catano	2,738.2127	0.2691	26
Hormigueros	2,674.2150	0.2628	27
Aguada	2,547.6497	0.2504	28
Canovanas	2,453.9711	0.2412	29
Vieques	1,825.2986	0.1794	30
Bayamon	1,818.2223	0.1787	31
San German	1,804.6357	0.1773	32
Gurabo	1,429.6209	0.1405	33
Fajardo	1,335.8118	0.1313	34
Penuelas	1,316.2098	0.1293	35
Caguas	998.4528	0.0981	36
Arroyo	968.1643	0.0951	37
Vega Alta	870.1229	0.0855	38
Luquillo	844.1161	0.083	39
Patillas	804.0050	0.079	40
Guaynabo	743.1405	0.073	41
Aguadilla	650.3363	0.0639	42
Maunabo	634.5043	0.0624	43
Yauco	487.4669	0.0479	44
Toa Alta	387.6786	0.0381	45
Cayey	336.1140	0.033	46
Juncos	178.0542	0.0175	47
Villalba	168.3872	0.0165	48
Rincon	165.8999	0.0163	49
Trujillo Alto	161.5943	0.0159	50
Hatillo	147.8753	0.0145	51
Isabela	146.9539	0.0144	52
Camuy	93.1579	0.0092	53
Las Piedras	79.4641	0.0078	54
Moca	74.5402	0.0073	55
San Sebastian	63.3458	0.0062	56
Quebradillas	54.6955	0.0054	57
Culebra	40.5576	0.004	58
Cidra	36.1906	0.0036	59
Utua	32.3615	0.0032	60
Ciales	17.9512	0.0018	61
Sabana Grande	10.4067	0.001	62
Comerio	8.6713	0.0009	63
Coamo	5.6327	0.0006	64
San Lorenzo	5.1369	0.0005	65
Jayuya	3.6277	0.0004	66

Morovis	3.8166	0.0004	66
Adjuntas	2.9882	0.0003	68
Aibonito	1.8615	0.0002	69
Las Marias	2.4885	0.0002	69
Naranjito	2.5023	0.0002	69
Aguas Buenas	0.5303	0.0001	72
Lares	1.3086	0.0001	72
Orocovis	1.5220	0.0001	72
Barranquitas	0.3593	0.0000	75
Corozal	0.4612	0.0000	75
Florida	0.0000	0.0000	75
Maricao	0.1579	0.0000	75

Hurricane Force Winds

Hazard Overview

Hurricanes and tropical storms are the most common natural hazard in Puerto Rico, causing extensive damage and loss. Hurricanes are tropical weather systems with a higher intensity of sustained winds at 74 miles per hour. They develop over warm waters and are caused by the instability created by the collision of warm and cool air. A hurricane is a type of tropical cyclone.

Tropical cyclones are classified according to the intensity of their sustained winds, namely:

1. Tropical Depression: An organized system of clouds with a defined circulation and maximum sustained winds which are less than 39 miles per hour. It is considered a tropical cyclone in its formative stage.
2. Tropical Storm: An organized system of clouds with a defined circulation and maximum sustained winds which fluctuate between 39 and 73 miles per hour.
3. Hurricane: A maximum intensity tropical cyclone at which the maximum sustained winds reach or exceed 74 miles per hour. It has a definite center with a very low barometric pressure in it. Hurricanes are classified into categories ranging from 1 to 5, and winds can reach over 155 miles per hour.

Hurricanes are dangerous because of their potential for destruction, their ability to affect large areas, their ability to form spontaneously, and their unpredictable movement. Hurricanes are often accompanied by high tides, storm surges, and heavy rains that can cause landslides and flooding by swollen rivers.

As an incipient hurricane develops, barometric pressure at its center falls and winds increase. If the atmospheric and oceanic conditions are favorable, it can intensify into a tropical depression. When maximum sustained winds reach or exceed 39 miles per hour, the system is designated a tropical storm, given a name and closely monitored by the National Hurricane Center in Miami, Florida. When sustained winds reach or exceed 74 miles per hour, the storm is deemed a hurricane. Hurricane

intensity is further classified by the Saffir-Simpson Scale, which rates hurricane intensity on a scale of 1 to 5, with 5 being the most intense. The Saffir-Simpson hurricane wind scale (Figure 3¹¹) categorizes hurricane intensity linearly based upon maximum sustained winds, barometric pressure and storm surge potential, which are combined to estimate potential damage.

Category	Sustained Winds	Types of Damage Due to Hurricane Winds
1	74-95 mph 64-82 kt 119-153 km/h	Very dangerous winds will produce some damage: Well-constructed frame homes could have damage to roof, shingles, vinyl siding and gutters. Large branches of trees will snap and shallowly rooted trees may be toppled. Extensive damage to power lines and poles likely will result in power outages that could last a few to several days.
2	96-110 mph 83-95 kt 154-177 km/h	Extremely dangerous winds will cause extensive damage: Well-constructed frame homes could sustain major roof and siding damage. Many shallowly rooted trees will be snapped or uprooted and block numerous roads. Near-total power loss is expected with outages that could last from several days to weeks.
3 (major)	111-129 mph 96-112 kt 178-208 km/h	Devastating damage will occur: Well-built framed homes may incur major damage or removal of roof decking and gable ends. Many trees will be snapped or uprooted, blocking numerous roads. Electricity and water will be unavailable for several days to weeks after the storm passes.
4 (major)	130-156 mph 113-136 kt 209-251 km/h	Catastrophic damage will occur: Well-built framed homes can sustain severe damage with loss of most of the roof structure and/or some exterior walls. Most trees will be snapped or uprooted and power poles downed. Fallen trees and power poles will isolate residential areas. Power outages will last weeks to possibly months. Most of the area will be uninhabitable for weeks or months.
5 (major)	157 mph or higher 137 kt or higher 252 km/h or higher	Catastrophic damage will occur: A high percentage of framed homes will be destroyed, with total roof failure and wall collapse. Fallen trees and power poles will isolate residential areas. Power outages will last for weeks to possibly months. Most of the area will be uninhabitable for weeks or months.

Figure 3: Saffir-Simpson Hurricane Wind Scale

Categories 3 – 5 hurricanes are classified as “major hurricanes”, and while hurricanes within this range comprise only 20% of US total tropical cyclone landfalls, they account for over 70% of the damage in the U.S.. Damage during hurricanes may also result from spawned tornadoes and inland flooding associated with heavy rainfall that usually accompanies these storms.

Data and Methods

Gaining perspective on historical frequencies of sustained hurricane force wind speeds across Puerto Rico required a multi-step geospatial process. First, we downloaded Extended Best Track (EBT) data for all Atlantic tropical cyclones from the National Hurricane Center¹². The National Hurricane Center (NHC) maintains a climatology of all Atlantic tropical cyclones since 1851, called HURDAT. For each storm, HURDAT contains estimates of the latitude, longitude, 1-minute maximum sustained surface winds, minimum sea-level pressure, and an indicator of whether the system was purely tropical, subtropical or extra-tropical at 6-hour intervals. However, HURDAT lacks any information about storm structure. By supplementing HURDAT with additional storm parameters determined by NHC, we created the “extended” best track file used here. The additional parameters include the following:

1. Maximum radial extent of 34, 50 and 64 kt wind in four quadrants
2. Radius of maximum wind
3. Eye diameter (if available)
4. Pressure and radius of the outer closed isobar

¹¹ <https://www.nhc.noaa.gov/aboutsshws.php>

¹² http://rammb.cira.colostate.edu/research/tropical_cyclones/tc_extended_best_track_dataset/

This EBT data was subset for Puerto Rico, resulting in a set of more than 624 6-hour locations for 77 tropical cyclones close enough to Puerto Rico to impact the island with winds (Figure 4A) between 1988 – 2018. The radius to maximum winds (for each point) was used to create a buffer around each point showing the most likely hurricane wind field. This fan shaped buffer (Figure 4B), created specifically for this assessment accounts for the general movement of hurricanes in this part of the Caribbean. Because most hurricanes travel in an East – West or Southeast – Northwest tract, compared to the more North-South pattern seen in the SE United States, the resulting winds associated with these storms is not on the east side of the storm generally, but rather on the north east. Each of the wind fields is then summarized to recreate a specific wind zone polygon for each hurricane event (Figure 4C) so that each storm is only counted once in the analytic process. Finally, a sum of the number of hurricanes impacted Puerto Rico between 1988 – 2018 is generated for each hex grid and summarized by municipio (Figure 4D).

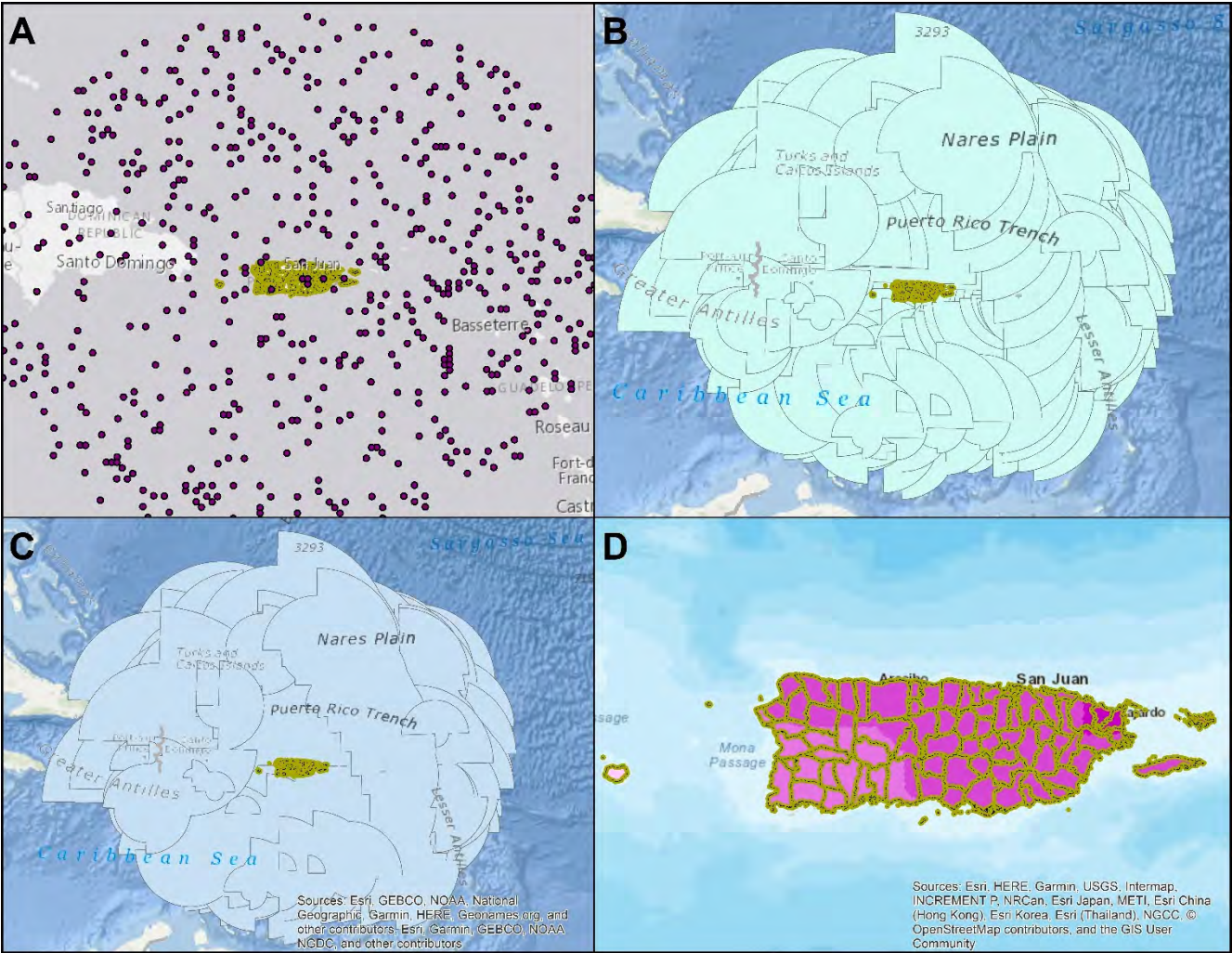


Figure 4: Hurricane Wind Hazard Frequency Analysis Process

Hazard Frequency Analysis Results

Eastern Puerto Rico has experienced more frequent hurricane wind speeds than the remainder of the island with the Isla de Mona experiencing the least number (8 instances) of hurricane force wind events. Fajardo and Luquillo Municipios are both completely within the highest category of hurricane frequency 19 – 21 with the islands east of Fajardo seeing 21 instances of hurricane winds during the last 30 years. Most of the remainder of central and northwestern Puerto Rico has seen between 16-18 hurricane-force wind events during this same time frame; and southeastern portions of the island have been impacted 13-15 times (Figure 5). Table 8 provides finer information about land area inside each hurricane-wind-frequency class by municipio. Table 9 details the percentage of total (municipio) land area in each zone for each municipio. Finally, Table 10 provides a breakdown of percentage of total island-wide land area in each category by municipio. This view can aid in an understanding of the differences across Puerto Rico in terms of hazard threats. Table 11 ranks each municipio by its overall hurricane wind frequency by land area.

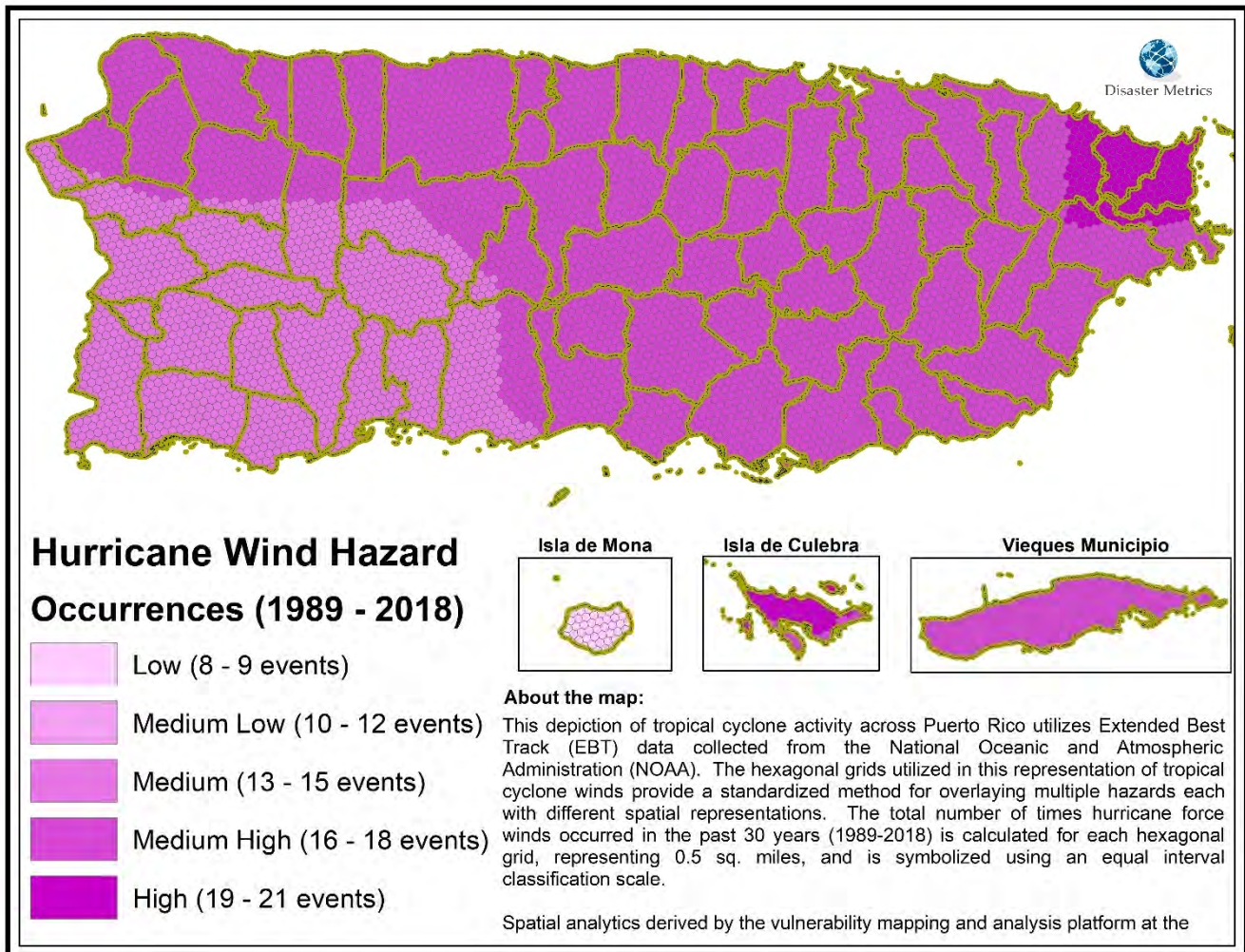


Figure 5: Hurricane Wind Hazard Areas

Table 8: Hurricane Wind Frequency by Municipio and Areal Extent

Municipio	HEX GRID Area by Hurricane Hazard Frequency (Sq. miles)				
	Low (8 – 9 Hurricanes)	Medium Low (10 - 12 Hurricanes)	Medium (13 - 15 Hurricanes)	Medium High (16 - 18 Hurricanes)	High (19 -21 Hurricanes)
Adjuntas			67.10		
Aguada			2.58	28.34	
Aguadilla				36.61	
Aguas Buenas				30.10	
Aibonito				31.34	
Anasco			32.21	7.35	
Arecibo				126.97	
Arroyo				15.05	
Barceloneta				18.76	
Barranquitas				34.28	
Bayamon				44.51	
Cabo Rojo			73.12		
Caguas				59.07	
Camuy				46.37	
Canovanas				33.01	
Cantano				47.30	
Carolina				5.08	
Cayey				51.96	
Ceiba				18.29	12.08
Ciales				66.71	
Cidra				36.46	
Coamo				78.03	
Comerio				28.52	
Corozal				42.58	
Culebra				3.37	9.94
Dorado				23.42	
Fajardo					30.51
Florida				15.22	
Guanica			39.01		
Guayama				65.87	
Guayanilla			42.99		
Guaynabo				27.76	
Gurabo				28.31	
Hatillo				41.84	
Hormigueros			11.34		
Humacao				45.10	
Isabela				55.41	

Jayuya			7.08	37.46	
Juana Diaz				60.73	
Juncos				26.62	
Lajas			61.36		
Lares			39.29	22.35	
Las Marias			46.50	0.00	
Las Piedras				33.89	
Loiza				20.53	
Luquillo					25.86
Manati				46.82	
Maricao			36.63		
Maunabo				21.09	
Mayaguez	22.18		55.79		
Moca				50.37	
Morovis				38.93	
Naguabo				45.57	6.31
Naranjito				27.75	
Orocovis				63.78	
Patillas				47.22	
Penuelas			44.76		
Ponce			73.97	43.01	
Quebradillas				23.14	
Rjo Grande			14.11	0.28	
Rincon				35.42	25.39
Sabana Grande			35.84		
Salinas				70.06	
San German			54.51		
San Juan				49.53	
San Lorenzo				53.21	
San Sebastian			12.69	58.53	
Santa Isabel				34.57	
Toa Alta				27.56	
Toa Baja				23.80	
Trujillo Alto				21.38	
Utuaado			46.96	68.11	
Vega Alta				27.74	
Vega Baja				46.65	
Vieques				53.18	
Villalba				37.04	
Yabucoa				55.41	
Yauco			68.82		
Grand Total	22.18	-	866.65	2,464.70	110.10

Table 9: Percent of (Municipio) Hexagonal Area by Hurricane Wind Frequency per Municipio

Municipio	Hurricane Wind Zone Percent Area by Total (Municipio) Land Area				
	Low (8 – 9 Hurricanes)	Medium Low (10 - 12 Hurricanes)	Medium (13 - 15 Hurricanes)	Medium High (16 - 18 Hurricanes)	High (19 -21 Hurricanes)
Adjuntas	0.00%	0.00%	100.00%	0.00%	0.00%
Aguada	0.00%	0.00%	8.35%	91.65%	0.00%
Aguadilla	0.00%	0.00%	0.00%	100.00%	0.00%
Aguas Buenas	0.00%	0.00%	0.00%	100.00%	0.00%
Aibonito	0.00%	0.00%	0.00%	100.00%	0.00%
Anasco	0.00%	0.00%	81.42%	18.58%	0.00%
Arecibo	0.00%	0.00%	0.00%	100.00%	0.00%
Arroyo	0.00%	0.00%	0.00%	100.00%	0.00%
Barceloneta	0.00%	0.00%	0.00%	100.00%	0.00%
Barranquitas	0.00%	0.00%	0.00%	100.00%	0.00%
Bayamon	0.00%	0.00%	0.00%	100.00%	0.00%
Cabo Rojo	0.00%	0.00%	100.00%	0.00%	0.00%
Caguas	0.00%	0.00%	0.00%	100.00%	0.00%
Camuy	0.00%	0.00%	0.00%	100.00%	0.00%
Canovanas	0.00%	0.00%	0.00%	100.00%	0.00%
Cantano	0.00%	0.00%	0.00%	100.00%	0.00%
Carolina	0.00%	0.00%	0.00%	100.00%	0.00%
Cayey	0.00%	0.00%	0.00%	100.00%	0.00%
Ceiba	0.00%	0.00%	0.00%	60.21%	39.79%
Ciales	0.00%	0.00%	0.00%	100.00%	0.00%
Cidra	0.00%	0.00%	0.00%	100.00%	0.00%
Coamo	0.00%	0.00%	0.00%	100.00%	0.00%
Comerio	0.00%	0.00%	0.00%	100.00%	0.00%
Corozal	0.00%	0.00%	0.00%	100.00%	0.00%
Culebra	0.00%	0.00%	0.00%	25.31%	74.69%
Dorado	0.00%	0.00%	0.00%	100.00%	0.00%
Fajardo	0.00%	0.00%	0.00%	0.00%	100.00%
Florida	0.00%	0.00%	0.00%	100.00%	0.00%
Guanica	0.00%	0.00%	100.00%	0.00%	0.00%
Guayama	0.00%	0.00%	0.00%	100.00%	0.00%
Guayanilla	0.00%	0.00%	100.00%	0.00%	0.00%
Guaynabo	0.00%	0.00%	0.00%	100.00%	0.00%
Gurabo	0.00%	0.00%	0.00%	100.00%	0.00%
Hatillo	0.00%	0.00%	0.00%	100.00%	0.00%
Hormigueros	0.00%	0.00%	100.00%	0.00%	0.00%
Humacao	0.00%	0.00%	0.00%	100.00%	0.00%

Isabela	0.00%	0.00%	0.00%	100.00%	0.00%
Jayuya	0.00%	0.00%	15.89%	84.11%	0.00%
Juana Diaz	0.00%	0.00%	0.00%	100.00%	0.00%
Juncos	0.00%	0.00%	0.00%	100.00%	0.00%
Lajas	0.00%	0.00%	100.00%	0.00%	0.00%
Lares	0.00%	0.00%	63.74%	36.26%	0.00%
Las Marias	0.00%	0.00%	100.00%	0.00%	0.00%
Las Piedras	0.00%	0.00%	0.00%	100.00%	0.00%
Loiza	0.00%	0.00%	0.00%	100.00%	0.00%
Luquillo	0.00%	0.00%	0.00%	0.00%	100.00%
Manati	0.00%	0.00%	0.00%	100.00%	0.00%
Maricao	0.00%	0.00%	100.00%	0.00%	0.00%
Maunabo	0.00%	0.00%	0.00%	100.00%	0.00%
Mayaguez	28.45%	0.00%	71.55%	0.00%	0.00%
Moca	0.00%	0.00%	0.00%	100.00%	0.00%
Morovis	0.00%	0.00%	0.00%	100.00%	0.00%
Naguabo	0.00%	0.00%	0.00%	87.83%	12.17%
Naranjito	0.00%	0.00%	0.00%	100.00%	0.00%
Orocovis	0.00%	0.00%	0.00%	100.00%	0.00%
Patillas	0.00%	0.00%	0.00%	100.00%	0.00%
Penuelas	0.00%	0.00%	100.00%	0.00%	0.00%
Ponce	0.00%	0.00%	63.23%	36.77%	0.00%
Quebradillas	0.00%	0.00%	0.00%	100.00%	0.00%
Rio Grande	0.00%	0.00%	98.07%	1.93%	0.00%
Rincon	0.00%	0.00%	0.00%	58.25%	41.75%
Sabana Grande	0.00%	0.00%	100.00%	0.00%	0.00%
Salinas	0.00%	0.00%	0.00%	100.00%	0.00%
San German	0.00%	0.00%	100.00%	0.00%	0.00%
San Juan	0.00%	0.00%	0.00%	100.00%	0.00%
San Lorenzo	0.00%	0.00%	0.00%	100.00%	0.00%
San Sebastian	0.00%	0.00%	17.81%	82.19%	0.00%
Santa Isabel	0.00%	0.00%	0.00%	100.00%	0.00%
Toa Alta	0.00%	0.00%	0.00%	100.00%	0.00%
Toa Baja	0.00%	0.00%	0.00%	100.00%	0.00%
Trujillo Alto	0.00%	0.00%	0.00%	100.00%	0.00%
Utuado	0.00%	0.00%	40.81%	59.19%	0.00%
Vega Alta	0.00%	0.00%	0.00%	100.00%	0.00%
Vega Baja	0.00%	0.00%	0.00%	100.00%	0.00%
Vieques	0.00%	0.00%	0.00%	100.00%	0.00%
Villalba	0.00%	0.00%	0.00%	100.00%	0.00%
Yabucoa	0.00%	0.00%	0.00%	100.00%	0.00%
Yauco	0.00%	0.00%	100.00%	0.00%	0.00%

Table 10: Percent of (Island) Hexagonal Area by Hurricane Wind Frequency Category per Municipio

Municipio	Hurricane Wind Percent Area by (Island) Land Area per Category				
	8 - 9 Hurricanes	10 - 12 Hurricanes	13 - 15 Hurricanes	16 - 18 Hurricanes	19 -21 Hurricanes
Adjuntas	0.00%	0.00%	7.74%	0.00%	0.00%
Aguada	0.00%	0.00%	0.30%	1.15%	0.00%
Aguadilla	0.00%	0.00%	0.00%	1.49%	0.00%
Aguas Buenas	0.00%	0.00%	0.00%	1.22%	0.00%
Aibonito	0.00%	0.00%	0.00%	1.27%	0.00%
Anasco	0.00%	0.00%	3.72%	0.30%	0.00%
Arecibo	0.00%	0.00%	0.00%	5.15%	0.00%
Arroyo	0.00%	0.00%	0.00%	0.61%	0.00%
Barceloneta	0.00%	0.00%	0.00%	0.76%	0.00%
Barranquitas	0.00%	0.00%	0.00%	1.39%	0.00%
Bayamon	0.00%	0.00%	0.00%	1.81%	0.00%
Cabo Rojo	0.00%	0.00%	8.44%	0.00%	0.00%
Caguas	0.00%	0.00%	0.00%	2.40%	0.00%
Camuy	0.00%	0.00%	0.00%	1.88%	0.00%
Canovanas	0.00%	0.00%	0.00%	1.34%	0.00%
Cantano	0.00%	0.00%	0.00%	1.92%	0.00%
Carolina	0.00%	0.00%	0.00%	0.21%	0.00%
Cayey	0.00%	0.00%	0.00%	2.11%	0.00%
Ceiba	0.00%	0.00%	0.00%	0.74%	10.98%
Ciales	0.00%	0.00%	0.00%	2.71%	0.00%
Cidra	0.00%	0.00%	0.00%	1.48%	0.00%
Coamo	0.00%	0.00%	0.00%	3.17%	0.00%
Comerio	0.00%	0.00%	0.00%	1.16%	0.00%
Corozal	0.00%	0.00%	0.00%	1.73%	0.00%
Culebra	0.00%	0.00%	0.00%	0.14%	9.03%
Dorado	0.00%	0.00%	0.00%	0.95%	0.00%
Fajardo	0.00%	0.00%	0.00%	0.00%	27.71%
Florida	0.00%	0.00%	0.00%	0.62%	0.00%
Guanica	0.00%	0.00%	4.50%	0.00%	0.00%
Guayama	0.00%	0.00%	0.00%	2.67%	0.00%
Guayanilla	0.00%	0.00%	4.96%	0.00%	0.00%
Guaynabo	0.00%	0.00%	0.00%	1.13%	0.00%
Gurabo	0.00%	0.00%	0.00%	1.15%	0.00%
Hatillo	0.00%	0.00%	0.00%	1.70%	0.00%
Hormigueros	0.00%	0.00%	1.31%	0.00%	0.00%
Humacao	0.00%	0.00%	0.00%	1.83%	0.00%
Isabela	0.00%	0.00%	0.00%	2.25%	0.00%

Jayuya	0.00%	0.00%	0.82%	1.52%	0.00%
Juana Diaz	0.00%	0.00%	0.00%	2.46%	0.00%
Juncos	0.00%	0.00%	0.00%	1.08%	0.00%
Lajas	0.00%	0.00%	7.08%	0.00%	0.00%
Lares	0.00%	0.00%	4.53%	0.91%	0.00%
Las Marias	0.00%	0.00%	5.37%	0.00%	0.00%
Las Piedras	0.00%	0.00%	0.00%	1.38%	0.00%
Loiza	0.00%	0.00%	0.00%	0.83%	0.00%
Luquillo	0.00%	0.00%	0.00%	0.00%	23.49%
Manati	0.00%	0.00%	0.00%	1.90%	0.00%
Maricao	0.00%	0.00%	4.23%	0.00%	0.00%
Maunabo	0.00%	0.00%	0.00%	0.86%	0.00%
Mayaguez	100.00%	0.00%	6.44%	0.00%	0.00%
Moca	0.00%	0.00%	0.00%	2.04%	0.00%
Morovis	0.00%	0.00%	0.00%	1.58%	0.00%
Naguabo	0.00%	0.00%	0.00%	1.85%	5.73%
Naranjito	0.00%	0.00%	0.00%	1.13%	0.00%
Orocovis	0.00%	0.00%	0.00%	2.59%	0.00%
Patillas	0.00%	0.00%	0.00%	1.92%	0.00%
Penuelas	0.00%	0.00%	5.16%	0.00%	0.00%
Ponce	0.00%	0.00%	8.54%	1.74%	0.00%
Quebradillas	0.00%	0.00%	0.00%	0.94%	0.00%
Rjo Grande	0.00%	0.00%	1.63%	0.01%	0.00%
Rincon	0.00%	0.00%	0.00%	1.44%	23.06%
Sabana Grande	0.00%	0.00%	4.14%	0.00%	0.00%
Salinas	0.00%	0.00%	0.00%	2.84%	0.00%
San German	0.00%	0.00%	6.29%	0.00%	0.00%
San Juan	0.00%	0.00%	0.00%	2.01%	0.00%
San Lorenzo	0.00%	0.00%	0.00%	2.16%	0.00%
San Sebastian	0.00%	0.00%	1.46%	2.37%	0.00%
Santa Isabel	0.00%	0.00%	0.00%	1.40%	0.00%
Toa Alta	0.00%	0.00%	0.00%	1.12%	0.00%
Toa Baja	0.00%	0.00%	0.00%	0.97%	0.00%
Trujillo Alto	0.00%	0.00%	0.00%	0.87%	0.00%
Utua	0.00%	0.00%	5.42%	2.76%	0.00%
Vega Alta	0.00%	0.00%	0.00%	1.13%	0.00%
Vega Baja	0.00%	0.00%	0.00%	1.89%	0.00%
Vieques	0.00%	0.00%	0.00%	2.16%	0.00%
Villalba	0.00%	0.00%	0.00%	1.50%	0.00%
Yabucoa	0.00%	0.00%	0.00%	2.25%	0.00%
Yauco	0.00%	0.00%	7.94%	0.00%	0.00%

Table 11: Hurricane Wind Hazard Scores and Ranks by Municipio

Municipio	Hurricane Wind Hazard Score (Log Multiplied)		
	Total Score	Standardized Score (0-1)	Rank of Score (1 – 78)
Fajardo	10,000.0000	1	1
Rincon	8,601.2126	0.8599	2
Luquillo	8,475.2237	0.8473	3
Ceiba	4,104.5095	0.4095	4
Culebra	3,284.2523	0.3274	5
Naguabo	2,428.0921	0.2416	6
Arecibo	1,000.0000	0.0986	7
Coamo	614.5134	0.06	8
Utua	599.9014	0.0585	9
Salinas	551.7524	0.0537	10
Ciales	525.3555	0.0511	11
Guayama	518.7459	0.0504	12
Orocovis	502.2673	0.0488	13
Juana Diaz	478.2996	0.0464	14
San Sebastian	478.1357	0.0464	14
Caguas	465.1916	0.0451	16
Ponce	438.7213	0.0424	17
Isabela	436.3739	0.0422	18
Yabucoa	436.3638	0.0422	18
San Lorenzo	419.0336	0.0404	20
Vieques	418.8500	0.0404	20
Cayey	409.2251	0.0394	22
Moca	396.6589	0.0382	23
San Juan	390.0546	0.0375	24
Cantano	372.5497	0.0358	25
Patillas	371.8471	0.0357	26
Manati	368.7413	0.0354	27
Vega Baja	367.3796	0.0353	28
Camuy	365.2022	0.035	29
Humacao	355.2197	0.034	30
Bayamon	350.5788	0.0336	31
Corozal	335.3358	0.032	32
Hatillo	329.5046	0.0315	33
Morovis	306.5592	0.0292	34
Jayuya	304.5742	0.029	35
Villalba	291.6759	0.0277	36
Aguadilla	288.2883	0.0273	37
Cidra	287.1063	0.0272	38

Santa Isabel	272.2921	0.0257	39
Barranquitas	269.9971	0.0255	40
Las Piedras	266.9227	0.0252	41
Canovanas	259.9412	0.0245	42
Aibonito	246.8095	0.0232	43
Aguas Buenas	237.0228	0.0222	44
Lares	229.1414	0.0214	45
Aguada	226.6967	0.0212	46
Comerio	224.6438	0.021	47
Gurabo	222.9817	0.0208	48
Guaynabo	218.6637	0.0204	49
Naranjito	218.5338	0.0204	49
Vega Alta	218.4715	0.0203	51
Toa Alta	217.0454	0.0202	52
Juncos	209.6111	0.0195	53
Toa Baja	187.4664	0.0172	54
Dorado	184.4249	0.0169	55
Quebradillas	182.2401	0.0167	56
Trujillo Alto	168.3949	0.0153	57
Maunabo	166.0878	0.0151	58
Loiza	161.7209	0.0147	59
Barceloneta	147.7382	0.0133	60
Florida	119.8846	0.0105	61
Arroyo	118.5062	0.0103	62
Anasco	101.4330	0.0086	63
Cabo Rojo	98.8461	0.0084	64
Yauco	93.0341	0.0078	65
Adjuntas	90.7043	0.0075	66
Lajas	82.9554	0.0068	67
Mayaguez	76.4225	0.0061	68
San German	73.6886	0.0058	69
Las Marias	62.8786	0.0048	70
Penuelas	60.5045	0.0045	71
Guayanilla	58.1161	0.0043	72
Guanica	52.7389	0.0037	73
Maricao	49.5151	0.0034	74
Sabana Grande	48.4541	0.0033	75
Carolina	40.0417	0.0025	76
Rio Grande	21.2643	0.0006	77
Hormigueros	15.3358	0	78

Rain Induced Landslides

Hazard Overview

According to the Puerto Rico's State Hazard Mitigation Plan¹³, landslides occur when the conditions for the force of gravity exerts its influence on crustal materials. The term landslide includes a wide variety of land movement, such as rock falls, slope failures, and debris flow. This earth movement threatens life and property and can disrupt transit, dragging trees, houses, bridges and cars, among others.

Meteorological phenomena that cause intense and prolonged rainfall, such as tropical waves and tropical cyclones can trigger landslides. Poor construction practices and population movement into hazard zones exacerbates the susceptibility of Puerto Rico to experience landslides.

Among the many factors causing the formation of landslides, the most important are: soil type, slope or incline of the terrain, soil water saturation, erosion, the presence of depressions or cavities, human activities, and of course the occurrence of earthquakes. As stated in the Building Performance Assessment Team Report (BPAT) prepared after Hurricane Georges, "landslides will become a major problem in the future as more houses are built and there is more development in areas susceptible to these risks" (FEMA, March 1999).

Many of the landslides that occur in Puerto Rico are in a special category of landslides known as "debris flow". The flow occurs in mountainous areas with significant slopes during heavy rains. The rain saturates the soil and causes the ground level and peel strength loss, usually where the ground makes contact with the bedrock. There are many types of landslides, however, associated with soil saturation by water:

1. Slow landslides: slow and steady movement of soil or rock falls down the slope, often recognized by their content of tree trunks, twisted pieces of fences or retaining walls, tilted poles or fences.
2. Debris flow: fast-moving mass which combines loose soils, rocks, organic matter, air infiltration and water to form a viscous flow that slides down the slope.
3. Debris avalanche: fast, or extremely fast, debris flow range.
4. Mud flow: mass rapid flow of wet material containing at least 50 percent sand, silt and clay particles.

¹³ Puerto Rico Hazard Mitigation Plan - <https://recovery.pr/en/document-library>

Data and Methods

The United State Geological Survey (USGS) completed a study of rainfall-induced landslides on Puerto Rico in early 2020.¹⁴ The report summarizes creation of a new high-resolution model of rainfall-induced landslide susceptibility for the main island. The main island of Puerto Rico was classified at 5-meter pixel scale into categories of Low, Moderate, High, Very High, or Extremely High susceptibility to landsliding during and soon after intense rainfall, such as is produced during tropical cyclones. Resulting raster GIS output data, downloaded as georeferenced files, were used in this assessment to understand sub-municipio level landslide susceptibility. The output grid of susceptibility index (SI) values were summarized for each ½ mile hexagonal grid and a focus on average landslide values was generated. Average SI values were used here because they enable visualization of spatial variation across the island, whereas summarized maximum SI values skew the visualization towards a much less realistic landslide threat (Figure 6).

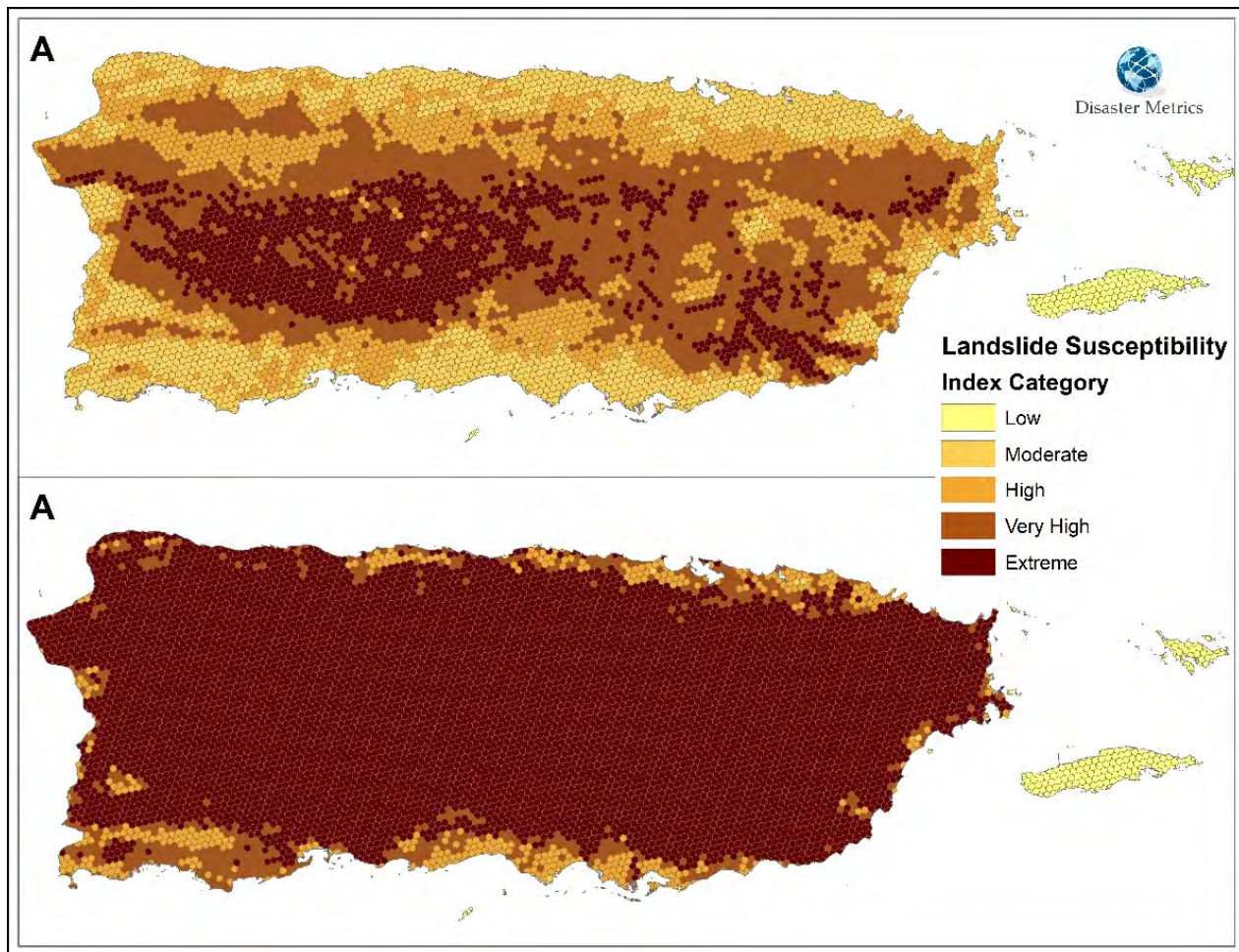


Figure 6: Rain Induced Landslide Susceptibility Index Average (A) vs Maximum (B) Score Comparison

¹⁴ <https://pubs.er.usgs.gov/publication/ofr20201022>

Hazard Frequency Analysis Results

Unlike flooding and hurricane hazards where coastal areas are more highly threatened, landslide hazards are mainly a hilly and mountainous area phenomena. Figure 6 illustrates higher landslide susceptibility along the west central portion of the island compared to the remainders of Puerto Rico. “Very high” landslide susceptibility trending from east to west coast and to the southeast indicates that landslide hazards are ever-present for many municipios.

Table 12 shows the total land area in each municipio by landslide susceptibility category. Here we see that places like Utuado (69 sq. mi.), Adjuntas (45.8 sq. mi.), and Ponce (40.6 sq. mi.) have the most land area in the “extreme” landslide category. However, Table 13 highlights places where more than 60% of their total land area in the “extreme” SI category. Included here are Maricao (94%), Jayuya (75%), Adjuntas (68%), and Las Marias (67%). Table 10 allows for a cross comparison between each municipio in reference to Puerto Rico as a whole. Finally, Table 15 shows rain induced landslide scores and ranks by municipio.

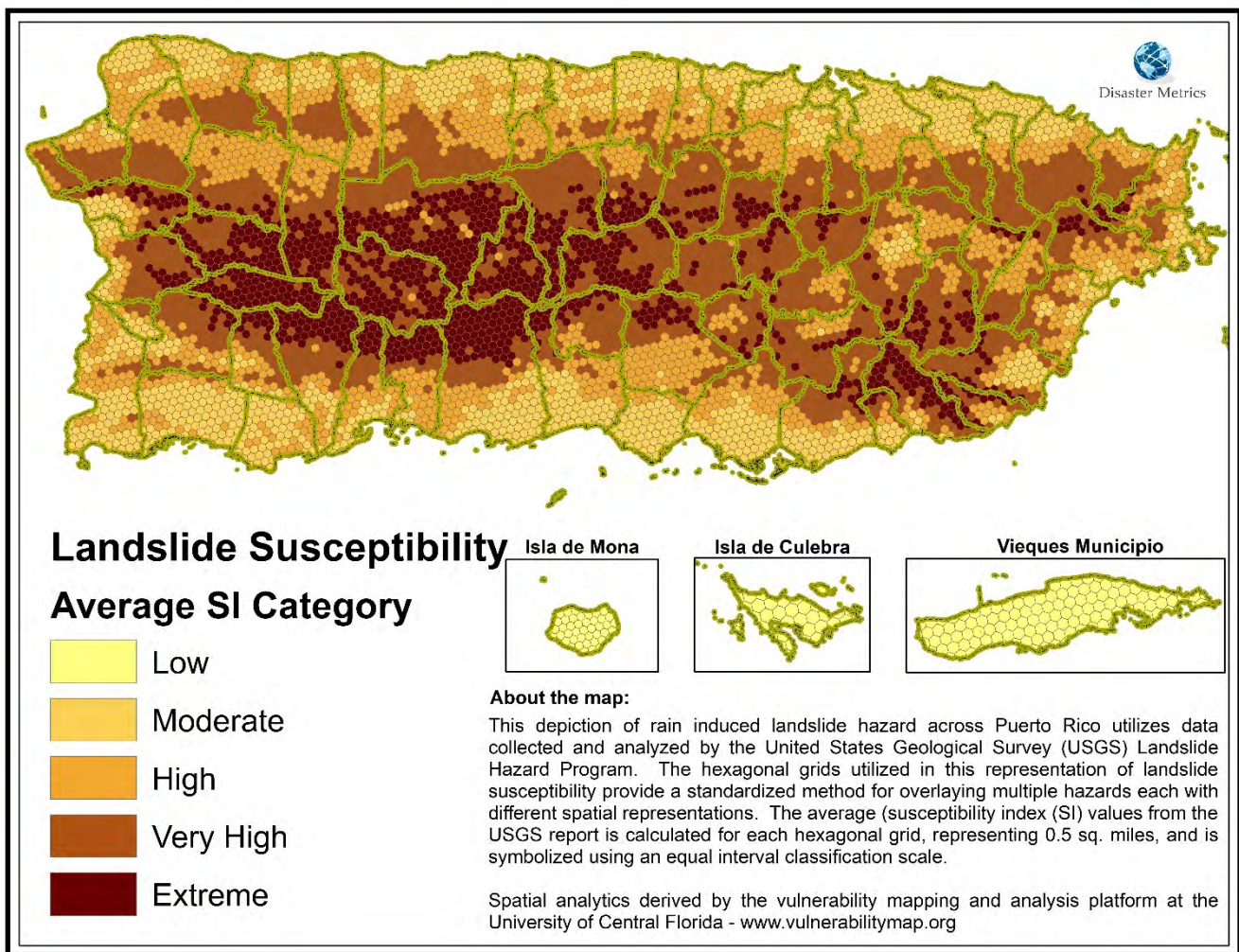


Figure 7: Rain Induced Landslide Susceptibility Areas

Table 12: Rain Induced Landslide Susceptibility by Municipio and Areal Extent

Municipio	HEX GRID Area by Landslide Susceptibility (Sq. miles)				
	Low (0 SI)	Moderate (1 - 25 SI)	High (25 - 50 SI)	Very High (50 - 75 SI)	Extreme (>75 SI)
Adjuntas			0.50	20.80	45.79
Aguada		6.08	8.24	15.92	0.68
Aguadilla		19.13	17.47	0.01	
Aguas Buenas			0.27	25.35	4.48
Aibonito			5.00	21.75	4.59
Anasco		8.88	4.34	13.44	12.90
Arecibo	0.00	38.82	46.28	41.87	0.00
Arroyo		6.33	2.02	4.35	2.35
Barceloneta	0.01	11.91	6.35	0.49	
Barranquitas			0.49	27.95	5.84
Bayamon		12.56	11.76	17.55	2.64
Cabo Rojo	0.00	44.70	24.41	4.01	
Caguas		6.49	14.73	32.03	5.83
Camuy		9.87	19.74	16.76	
Canovanas		7.18	5.59	19.37	0.86
Carolina		24.59	6.29	16.42	0.00
Catano		5.08			
Cayey		0.50	7.70	35.43	8.33
Ceiba	0.80	11.36	7.34	8.28	2.59
Ciales			2.05	42.04	22.62
Cidra			9.73	25.77	0.96
Coamo		1.20	36.91	28.14	11.78
Comerio			0.00	21.30	7.22
Corozal			1.43	30.89	10.25
Culebra	13.31				
Dorado		13.01	8.91	1.50	
Fajardo	0.56	5.85	15.09	6.21	2.80
Florida			10.83	4.40	
Guanica	0.01	29.69	9.31		
Guayama	0.13	23.31	11.41	24.24	6.78
Guayanilla	0.14	11.40	14.15	8.47	8.83
Guaynabo		3.98	7.93	14.85	1.00
Gurabo		0.51	12.22	15.17	0.41
Hatillo		10.57	20.74	10.53	
Hormigueros		6.34	1.50	3.51	

Humacao	0.18	11.15	17.87	15.90	
Isabela		17.54	15.54	22.32	
Jayuya			0.50	10.54	33.50
Juana Diaz	0.12	26.52	18.97	8.59	6.53
Juncos			12.36	10.88	3.38
Lajas	0.17	45.90	12.94	2.35	
Lares			14.24	20.61	26.80
Las Marias				15.11	31.39
Las Piedras			12.88	19.43	1.59
Loiza		20.45	0.08		
Luquillo		2.62	9.55	13.06	0.63
Manati	0.20	17.63	22.29	6.71	
Maricao				2.26	34.37
Maunabo	0.00	1.38	5.14	5.76	8.81
Mayaguez	22.77	10.98	7.42	26.82	9.99
Moca		2.47	20.80	27.09	0.01
Morovis			11.47	14.76	12.69
Naguabo	0.01	7.19	18.32	21.17	5.18
Naranjito			0.02	20.23	7.49
Orocovis				27.76	36.01
Patillas	0.00	2.47	4.90	15.52	24.32
Penuelas	0.13	3.32	16.90	7.46	16.95
Ponce	0.65	34.91	21.01	19.86	40.55
Quebradillas		5.95	10.51	6.69	
Rincon	0.09	0.62	4.29	8.62	0.77
Rio Grande		12.90	13.37	33.25	1.29
Sabana Grande		5.37	10.74	12.37	7.37
Salinas	0.39	33.75	21.66	14.06	0.20
San German		6.12	13.25	29.41	5.73
San Juan	0.00	24.57	17.05	7.91	
San Lorenzo			4.90	33.37	14.94
San Sebastian			35.10	29.13	6.99
Santa Isabel	0.11	28.99	5.34	0.13	
Toa Alta		0.18	17.64	9.74	
Toa Baja	0.00	16.63	7.17		
Trujillo Alto			7.95	13.43	
Utua			3.69	42.33	69.05
Vega Alta		7.32	13.16	7.27	
Vega Baja	0.00	21.73	16.83	8.08	
Vieques	53.18				
Villalba			6.37	21.99	8.68
Yabucoa		11.09	8.71	26.79	8.82

Yauco		7.75	11.63	21.99	27.45
Grand Total	92.98	706.84	823.29	1219.52	621.00

Table 13: Percent of (Municipio) Hexagonal Area by Rain Induced Landslide Susceptibility per Municipio

Municipio	Landslide Susceptibility Percent Area by Total (Municipio) Land Area				
	Low (0 SI)	Moderate (1 - 25 SI)	High (25 - 50 SI)	Very High (50 - 75 SI)	Extreme (>75 SI)
Adjuntas	0.00%	0.00%	0.75%	31.01%	68.25%
Aguada	0.00%	19.67%	26.65%	51.49%	2.19%
Aguadilla	0.00%	52.25%	47.73%	0.02%	0.00%
Aguas Buenas	0.00%	0.00%	0.89%	84.22%	14.90%
Aibonito	0.00%	0.00%	15.95%	69.41%	14.63%
Anasco	0.00%	22.45%	10.98%	33.98%	32.60%
Arecibo	0.00%	30.57%	36.45%	32.98%	0.00%
Arroyo	0.00%	42.07%	13.46%	28.88%	15.59%
Barceloneta	0.06%	63.49%	33.86%	2.59%	0.00%
Barranquitas	0.00%	0.00%	1.44%	81.53%	17.03%
Bayamon	0.00%	28.21%	26.42%	39.43%	5.93%
Cabo Rojo	0.00%	61.13%	33.38%	5.48%	0.00%
Caguas	0.00%	10.99%	24.93%	54.22%	9.86%
Camuy	0.00%	21.28%	42.57%	36.15%	0.00%
Canovanas	0.00%	21.77%	16.93%	58.70%	2.61%
Carolina	0.00%	51.99%	13.29%	34.71%	0.01%
Catano	0.00%	100.00%	0.00%	0.00%	0.00%
Cayey	0.00%	0.96%	14.82%	68.19%	16.03%
Ceiba	2.63%	37.40%	24.18%	27.26%	8.53%
Ciales	0.00%	0.00%	3.07%	63.02%	33.92%
Cidra	0.00%	0.00%	26.69%	70.69%	2.63%
Coamo	0.00%	1.54%	47.30%	36.06%	15.10%
Comerio	0.00%	0.00%	0.00%	74.68%	25.32%
Corozal	0.00%	0.00%	3.37%	72.55%	24.08%
Culebra	100.00%	0.00%	0.00%	0.00%	0.00%
Dorado	0.00%	55.56%	38.04%	6.41%	0.00%
Fajardo	1.83%	19.16%	49.47%	20.35%	9.19%
Florida	0.00%	0.00%	71.12%	28.88%	0.00%
Guanica	0.03%	76.12%	23.85%	0.00%	0.00%
Guayama	0.19%	35.39%	17.33%	36.79%	10.29%
Guayanilla	0.33%	26.52%	32.90%	19.70%	20.54%
Guaynabo	0.00%	14.33%	28.57%	53.50%	3.60%
Gurabo	0.00%	1.80%	43.17%	53.60%	1.44%
Hatillo	0.00%	25.25%	49.58%	25.17%	0.00%
Hormigueros	0.00%	55.86%	13.24%	30.91%	0.00%

Humacao	0.40%	24.73%	39.61%	35.25%	0.00%
Isabela	0.00%	31.66%	28.05%	40.29%	0.00%
Jayuya	0.00%	0.00%	1.12%	23.66%	75.22%
Juana Diaz	0.19%	43.67%	31.23%	14.15%	10.75%
Juncos	0.00%	0.00%	46.43%	40.86%	12.70%
Lajas	0.28%	74.81%	21.09%	3.83%	0.00%
Lares	0.00%	0.00%	23.10%	33.43%	43.47%
Las Marias	0.00%	0.00%	0.00%	32.50%	67.50%
Las Piedras	0.00%	0.00%	38.00%	57.32%	4.68%
Loiza	0.00%	99.60%	0.40%	0.00%	0.00%
Luquillo	0.00%	10.11%	36.94%	50.51%	2.44%
Manati	0.43%	37.65%	47.60%	14.32%	0.00%
Maricao	0.00%	0.00%	0.00%	6.17%	93.83%
Maunabo	0.00%	6.55%	24.38%	27.31%	41.76%
Mayaguez	29.20%	14.08%	9.51%	34.40%	12.81%
Moca	0.00%	4.90%	41.29%	53.79%	0.02%
Morovis	0.00%	0.00%	29.47%	37.93%	32.61%
Naguabo	0.02%	13.86%	35.31%	40.81%	9.99%
Naranjito	0.00%	0.00%	0.08%	72.92%	27.00%
Orocovis	0.00%	0.00%	0.00%	43.53%	56.47%
Patillas	0.01%	5.24%	10.38%	32.87%	51.50%
Penuelas	0.30%	7.41%	37.76%	16.66%	37.87%
Ponce	0.55%	29.84%	17.96%	16.97%	34.66%
Quebradillas	0.00%	25.70%	45.40%	28.90%	0.00%
Rincon	0.60%	4.33%	29.79%	59.93%	5.36%
Rio Grande	0.00%	21.21%	21.99%	54.68%	2.12%
Sabana Grande	0.00%	14.97%	29.96%	34.50%	20.57%
Salinas	0.56%	48.17%	30.92%	20.06%	0.29%
San German	0.00%	11.23%	24.30%	53.96%	10.51%
San Juan	0.00%	49.62%	34.42%	15.96%	0.00%
San Lorenzo	0.00%	0.00%	9.20%	62.72%	28.07%
San Sebastian	0.00%	0.00%	49.29%	40.90%	9.81%
Santa Isabel	0.32%	83.86%	15.44%	0.38%	0.00%
Toa Alta	0.00%	0.66%	64.00%	35.34%	0.00%
Toa Baja	0.00%	69.87%	30.13%	0.00%	0.00%
Trujillo Alto	0.00%	0.00%	37.20%	62.80%	0.00%
Utua	0.00%	0.00%	3.20%	36.79%	60.01%
Vega Alta	0.00%	26.38%	47.43%	26.19%	0.00%
Vega Baja	0.00%	46.59%	36.09%	17.32%	0.00%
Vieques	100.00%	0.00%	0.00%	0.00%	0.00%
Villalba	0.00%	0.00%	17.20%	59.36%	23.44%
Yabucoa	0.00%	20.01%	15.72%	48.35%	15.91%

Yauco	0.00%	11.26%	16.91%	31.95%	39.89%
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Table 14: Percent of (Island) Hexagonal Area by Rain Induced Landslide Susceptibility per Municipio

Municipio	Landslide Susceptibility Percent Area by Total (Island) Land Area Per Category				
	Low (0 SI)	Moderate (1 - 25 SI)	High (25 - 50 SI)	Very High (50 - 75 SI)	Extreme (>75 SI)
Adjuntas	0.00%	0.00%	0.00%	2.00%	7.00%
Aguada	0.00%	1.00%	1.00%	1.00%	0.00%
Aguadilla	0.00%	3.00%	2.00%	0.00%	0.00%
Aguas Buenas	0.00%	0.00%	0.00%	2.00%	1.00%
Aibonito	0.00%	0.00%	1.00%	2.00%	1.00%
Anasco	0.00%	1.00%	1.00%	1.00%	2.00%
Arecibo	0.00%	5.00%	6.00%	3.00%	0.00%
Arroyo	0.00%	1.00%	0.00%	0.00%	0.00%
Barceloneta	0.00%	2.00%	1.00%	0.00%	0.00%
Barranquitas	0.00%	0.00%	0.00%	2.00%	1.00%
Bayamon	0.00%	2.00%	1.00%	1.00%	0.00%
Cabo Rojo	0.00%	6.00%	3.00%	0.00%	0.00%
Caguas	0.00%	1.00%	2.00%	3.00%	1.00%
Camuy	0.00%	1.00%	2.00%	1.00%	0.00%
Canovanas	0.00%	1.00%	1.00%	2.00%	0.00%
Carolina	0.00%	3.00%	1.00%	1.00%	0.00%
Catano	0.00%	1.00%	0.00%	0.00%	0.00%
Cayey	0.00%	0.00%	1.00%	3.00%	1.00%
Ceiba	1.00%	2.00%	1.00%	1.00%	0.00%
Ciales	0.00%	0.00%	0.00%	3.00%	4.00%
Cidra	0.00%	0.00%	1.00%	2.00%	0.00%
Coamo	0.00%	0.00%	4.00%	2.00%	2.00%
Comerio	0.00%	0.00%	0.00%	2.00%	1.00%
Corozal	0.00%	0.00%	0.00%	3.00%	2.00%
Culebra	14.00%	0.00%	0.00%	0.00%	0.00%
Dorado	0.00%	2.00%	1.00%	0.00%	0.00%
Fajardo	1.00%	1.00%	2.00%	1.00%	0.00%
Florida	0.00%	0.00%	1.00%	0.00%	0.00%
Guanica	0.00%	4.00%	1.00%	0.00%	0.00%
Guayama	0.00%	3.00%	1.00%	2.00%	1.00%
Guayanilla	0.00%	2.00%	2.00%	1.00%	1.00%
Guaynabo	0.00%	1.00%	1.00%	1.00%	0.00%
Gurabo	0.00%	0.00%	1.00%	1.00%	0.00%
Hatillo	0.00%	1.00%	3.00%	1.00%	0.00%
Hormigueros	0.00%	1.00%	0.00%	0.00%	0.00%
Humacao	0.00%	2.00%	2.00%	1.00%	0.00%

Isabela	0.00%	2.00%	2.00%	2.00%	0.00%
Jayuya	0.00%	0.00%	0.00%	1.00%	5.00%
Juana Diaz	0.00%	4.00%	2.00%	1.00%	1.00%
Juncos	0.00%	0.00%	2.00%	1.00%	1.00%
Lajas	0.00%	6.00%	2.00%	0.00%	0.00%
Lares	0.00%	0.00%	2.00%	2.00%	4.00%
Las Marias	0.00%	0.00%	0.00%	1.00%	5.00%
Las Piedras	0.00%	0.00%	2.00%	2.00%	0.00%
Loiza	0.00%	3.00%	0.00%	0.00%	0.00%
Luquillo	0.00%	0.00%	1.00%	1.00%	0.00%
Manati	0.00%	2.00%	3.00%	1.00%	0.00%
Maricao	0.00%	0.00%	0.00%	0.00%	6.00%
Maunabo	0.00%	0.00%	1.00%	0.00%	1.00%
Mayaguez	24.00%	2.00%	1.00%	2.00%	2.00%
Moca	0.00%	0.00%	3.00%	2.00%	0.00%
Morovis	0.00%	0.00%	1.00%	1.00%	2.00%
Naguabo	0.00%	1.00%	2.00%	2.00%	1.00%
Naranjito	0.00%	0.00%	0.00%	2.00%	1.00%
Orocovis	0.00%	0.00%	0.00%	2.00%	6.00%
Patillas	0.00%	0.00%	1.00%	1.00%	4.00%
Penuelas	0.00%	0.00%	2.00%	1.00%	3.00%
Ponce	1.00%	5.00%	3.00%	2.00%	7.00%
Quebradillas	0.00%	1.00%	1.00%	1.00%	0.00%
Rincon	0.00%	0.00%	1.00%	1.00%	0.00%
Rio Grande	0.00%	2.00%	2.00%	3.00%	0.00%
Sabana Grande	0.00%	1.00%	1.00%	1.00%	1.00%
Salinas	0.00%	5.00%	3.00%	1.00%	0.00%
San German	0.00%	1.00%	2.00%	2.00%	1.00%
San Juan	0.00%	3.00%	2.00%	1.00%	0.00%
San Lorenzo	0.00%	0.00%	1.00%	3.00%	2.00%
San Sebastian	0.00%	0.00%	4.00%	2.00%	1.00%
Santa Isabel	0.00%	4.00%	1.00%	0.00%	0.00%
Toa Alta	0.00%	0.00%	2.00%	1.00%	0.00%
Toa Baja	0.00%	2.00%	1.00%	0.00%	0.00%
Trujillo Alto	0.00%	0.00%	1.00%	1.00%	0.00%
Utua	0.00%	0.00%	0.00%	3.00%	11.00%
Vega Alta	0.00%	1.00%	2.00%	1.00%	0.00%
Vega Baja	0.00%	3.00%	2.00%	1.00%	0.00%
Vieques	57.00%	0.00%	0.00%	0.00%	0.00%
Villalba	0.00%	0.00%	1.00%	2.00%	1.00%
Yabucoa	0.00%	2.00%	1.00%	2.00%	1.00%
Yauco	0.00%	1.00%	1.00%	2.00%	4.00%

Table 15: Rain Induced Landslide Hazard Scores and Ranks by Municipio

Municipio	Rain Induced Landslide Hazard Score (Log Multiplied)		
	Total Score	Standardized Score (0-1)	Rank of Score (1 -78)
Utua	11,007.9658	1	1
Adjuntas	7,124.2914	0.6472	2
Ponce	6,394.7789	0.5809	3
Orocovis	5,871.2660	0.5334	4
Jayuya	5,101.2950	0.4634	5
Maricao	5,030.6125	0.457	6
Las Marias	4,903.4308	0.4454	7
Yauco	4,521.8364	0.4108	8
Lares	4,398.3440	0.3995	9
Ciales	4,273.9571	0.3882	10
Patillas	3,899.4960	0.3542	11
San Lorenzo	2,961.9372	0.2691	12
Penuelas	2,668.3423	0.2424	13
Coamo	2,450.5625	0.2226	14
Corozal	2,217.8701	0.2015	15
Morovis	2,211.6440	0.2009	16
Anasco	2,196.3652	0.1995	17
Mayaguez	2,098.8878	0.1907	18
Cayey	2,059.6981	0.1871	19
Yabucoa	1,931.0546	0.1754	20
Villalba	1,790.1072	0.1626	21
San Sebastian	1,776.1361	0.1613	22
Caguas	1,633.3541	0.1484	23
Guayama	1,584.0420	0.1439	24
Naranjito	1,563.0970	0.142	25
San German	1,554.7317	0.1412	26
Comerio	1,549.2521	0.1407	27
Guayanilla	1,512.2217	0.1374	28
Barranquitas	1,506.8275	0.1369	29
Maunabo	1,422.8750	0.1292	30
Sabana Grande	1,384.4359	0.1257	31
Naguabo	1,291.9654	0.1173	32
Aguas Buenas	1,248.5177	0.1134	33
Juana Diaz	1,195.6958	0.1086	34
Aibonito	1,188.8122	0.108	35
Arecibo	1,097.5492	0.0997	36
Rio Grande	1,004.0051	0.0912	37
Bayamon	825.1892	0.0749	38

Juncos	773.2950	0.0702	39
Cidra	768.3763	0.0698	40
Las Piedras	716.3653	0.0651	41
Moca	686.9647	0.0624	42
Canovanas	595.9398	0.0541	43
Ceiba	589.2291	0.0535	44
Fajardo	586.7743	0.0533	45
Isabela	564.7305	0.0513	46
Guaynabo	513.6940	0.0466	47
Aguada	493.4421	0.0448	48
Arroyo	448.1762	0.0407	49
Gurabo	443.8242	0.0403	50
Camuy	440.7746	0.04	51
Luquillo	421.0537	0.0382	52
Humacao	416.6406	0.0378	53
Salinas	415.5659	0.0377	54
Carolina	407.3304	0.037	55
Trujillo Alto	334.3882	0.0304	56
Rincon	324.8197	0.0295	57
Hatillo	295.8386	0.0269	58
Toa Alta	268.1891	0.0243	59
Vega Baja	231.9846	0.0211	60
San Juan	228.9270	0.0208	61
Manati	210.3993	0.0191	62
Vega Alta	201.6417	0.0183	63
Quebradillas	181.9432	0.0165	64
Cabo Rojo	157.1405	0.0143	65
Florida	127.2404	0.0115	66
Lajas	93.4171	0.0085	67
Hormigueros	87.4430	0.0079	68
Dorado	57.5182	0.0052	69
Aguadilla	42.0751	0.0038	70
Barceloneta	27.8045	0.0025	71
Guanica	26.5750	0.0024	72
Santa Isabel	20.9251	0.0019	73
Toa Baja	19.1187	0.0017	74
Loiza	4.6317	0.0004	75
Catano	1.1076	0.0001	76
Vieques	1.0000	0.0001	76
Culebra	0.2502	0	78

Severe Storms

Hazard Overview

Severe thunderstorms are defined by the National Weather Service as storms that have wind speeds of 58 miles per hour or higher, produce hail at least ¼ inches in diameter, or produces tornadoes. Thunderstorms simply require moisture to form clouds and rain, coupled with an unstable mass of warm air that can rise rapidly.

Thunderstorms affect relatively small areas when compared with hurricanes and winter storms, as the average storm is 15 miles in diameter and lasts an average of 30 minutes. Nearly 1,800 thunderstorms are occurring at any moment around the world. However, of the estimated 100,000 thunderstorms that occur each year in the United States only about 10 percent are classified as severe. Thunderstorms are most likely to happen in the spring and summer months and during the afternoon and evening hours but can occur year-round and at all hours.

Despite their small size, all thunderstorms are dangerous and capable of threatening life and property in localized areas. Every thunderstorm produces lightning, which results from the buildup and discharge of electrical energy between positively and negatively charged areas. Each year across the US, lightning is responsible for an average of 93 deaths (more than tornados), 300 injuries, and several hundred million dollars in damage to property and forests.

Thunderstorms can also produce large, damaging hail, which causes nearly \$1 billion in damage to property and crops annually. Straight-line winds, which in extreme cases have the potential to exceed 100 miles per hour, are responsible for most thunderstorm wind damage. One type of straight-line wind, the downburst, can cause damage equivalent to a strong tornado and can be extremely dangerous to aviation. Thunderstorms are also capable of producing tornados and heavy rain that can lead to flash flooding.

Data and Methods

Severe storm warnings are issued by Puerto Rico's National Weather Service Forecast Office. Severe Thunderstorm Warnings will include where the storm was located, what towns will be affected by the severe thunderstorm, and the primary threat associated with the severe thunderstorm warning.¹⁵ Archived severe storm warnings are collected and archived by Iowa State University's Environmental Mesonet.¹⁶ Across Puerto Rico, there have been forty-four severe storm warnings issued between 2002-2019 (Figure 8). Each hexagonal grid was appraised based on the number of watch boxes

¹⁵ <https://www.weather.gov/bgm/severedefinitions>

¹⁶ <https://mesonet.agron.iastate.edu/>

touching it over the time period of record. This summation was then divided by the number of years in record to develop an average annual number of severe storms, and mapped.

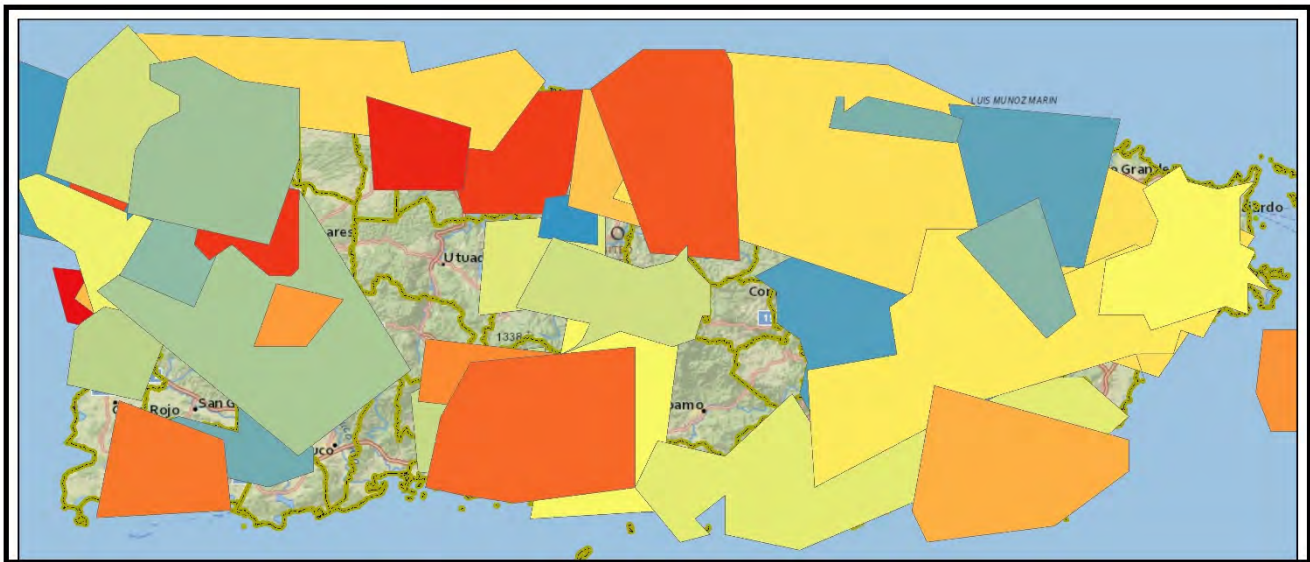


Figure 8: Severe Storm Watch Boxes for Puerto Rico 2002-2019.

Hazard Frequency Analysis Results

The relatively low number of severe storm warnings across the island, (3.6 per year) indicates that severe storms occur less often in relation to other portions of the United States. However, because severe storms can have dire consequences no matter how infrequently they occur. Western portions of the island tend to have a higher number of severe storms than other portions; nearly 70% of San Sebastián’s land area is in a high severe storm zone (Figure 9). Six municipios across Puerto Rico have some area in high hazard zones and another 27 have some area in medium high severe storm zones (Table 16). Municipios such as Anasco, and Las Marias have around 25% of their land area in high severe storm hazard zones (Table 17). Table 18 provides a breakdown of total island land areas by severe storm category and municipio and Table 19 sums and ranks severe storm risk for each municipio across the island.

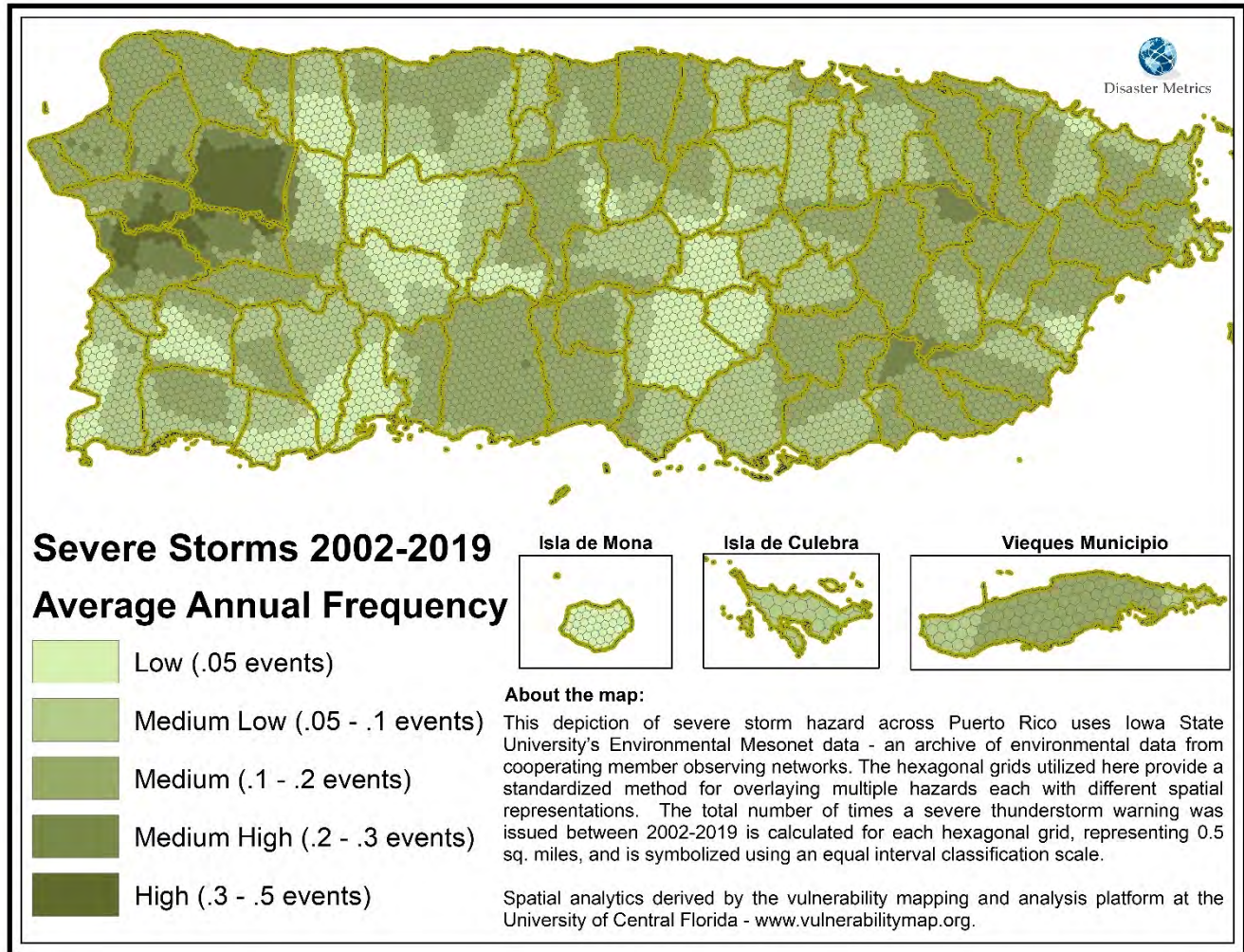


Figure 9: Severe Storm Hazard Frequency Areas

Table 16: Severe Storm Hazard Frequency by Municipio and Areal Extent

Municipio	HEX GRID Area by Severe Storm Frequency (Sq. miles)				
	Low ($<.05$ events)	Medium Low ($.05 - .1$ events)	Medium ($.1 - .2$ events)	Medium High ($.2 - .3$ events)	High ($.3 - .5$ events)
Adjuntas	30.42	34.88	1.79		
Aguada			28.64	2.29	
Aguadilla			36.46	0.14	
Aguas Buenas		8.70	21.40		
Aibonito	25.14	5.89	0.31		
Anasco		1.21	14.97	14.44	8.95
Arecibo	8.70	60.14	58.13		
Arroyo		2.37	12.68	0.00	
Barceloneta	0.01	17.43	1.31		
Barranquitas	29.17	5.11			
Bayamon		40.11	4.40		
Cabo Rojo	25.67	46.45	1.00		

Caguas		0.15	58.92		
Camuy	26.04	18.56	1.72	0.05	
Canovanas			31.87	1.14	
Cantano			45.51	1.80	
Carolina		0.74	4.35		
Cayey		0.52	51.19	0.26	
Ceiba	2.67	9.00	18.70		
Ciales	4.45	12.54	49.72		
Cidra	0.03	29.68	6.74		
Coamo	55.80	19.96	2.27		
Comerio	0.42	26.55	1.56		
Corozal	6.90	18.21	17.47		
Culebra	0.65	12.66			
Dorado		22.34	1.07		
Fajardo	2.25	10.31	17.95		
Florida		10.18	5.05		
Guanica	21.73	16.49	0.79		
Guayama		33.64	32.16	0.06	
Guayanilla	34.32	8.67			
Guaynabo		23.31	4.45		
Gurabo			18.33	9.99	
Hatillo	10.66	19.62	11.56		
Hormigueros	0.72	10.60	0.03		
Humacao	8.14	10.74	26.22		
Isabela		7.29	48.06	0.06	
Jayuya	14.89	11.45	18.03	0.16	
Juana Diaz	0.12	4.66	55.71	0.25	
Juncos		1.31	23.83	1.48	
Lajas	1.29	31.89	28.18		
Lares	13.47	29.51	12.85	5.82	0.00
Las Marias		1.14	14.06	19.42	11.89
Las Piedras		8.86	25.03		
Loiza		7.16	13.37		
Luquillo	0.15	10.22	15.49		
Manati		12.98	33.84		
Maricao		6.98	29.62	0.03	
Maunabo			21.09		
Mayaguez	22.77	4.04	13.00	25.14	13.02
Moca			40.96	7.68	1.73
Morovis	3.55	12.29	23.08		
Naguabo		0.39	51.49		
Naranjito	3.32	22.43	2.00		

Orocovis	0.27	43.03	20.04	0.44	
Patillas	0.00	0.16	37.10	9.96	
Penuelas	5.76	11.77	27.22		
Ponce	1.05	6.05	109.23	0.65	
Quebradillas	0.08	9.96	13.02	0.07	
Rjo Grande		0.09	14.30		
Rincon	6.31	26.62	27.88		
Sabana Grande		16.91	18.93		
Salinas	0.11	58.51	11.43		
San German	22.25	18.08	14.18		
San Juan		32.34	17.19		
San Lorenzo		19.52	29.24	4.44	
San Sebastian	0.04	2.01	5.40	14.35	49.41
Santa Isabel	0.33	24.42	9.82		
Toa Alta		26.79	0.77		
Toa Baja		19.01	4.80		
Trujillo Alto		7.95	11.33	2.10	
Utuado	78.13	35.24	1.71		
Vega Alta		1.55	26.19		
Vega Baja		0.03	46.62		
Vieques		12.85	40.33		
Villalba		8.48	28.56		
Yabucoa		20.23	32.89	2.28	
Yauco	16.62	47.25	4.95		
Grand Total	484.45	1,158.16	1,611.54	124.49	85.00

Table 17: Percent of (Municipio) Hexagonal Area by Severe Storm Hazard Frequency per Municipio

Municipio	Severe Storm Percent Area by Total (Municipio) Land Area				
	Low (<.05 events)	Medium Low (.05 - .1 events)	Medium (.1 - .2 events)	Medium High (.2 - .3 events)	High (.3 - .5 events)
Adjuntas	45.35%	51.98%	2.67%	0.00%	0.00%
Aguada	0.00%	0.00%	92.60%	7.40%	0.00%
Aguadilla	0.00%	0.00%	99.61%	0.39%	0.00%
Aguas Buenas	0.00%	28.91%	71.09%	0.00%	0.00%
Aibonito	80.23%	18.78%	0.99%	0.00%	0.00%
Anasco	0.00%	3.05%	37.84%	36.49%	22.62%
Arecibo	6.86%	47.36%	45.78%	0.00%	0.00%
Arroyo	0.00%	15.72%	84.27%	0.01%	0.00%
Barceloneta	0.06%	92.94%	7.00%	0.00%	0.00%
Barranquitas	85.09%	14.91%	0.00%	0.00%	0.00%
Bayamon	0.00%	90.11%	9.89%	0.00%	0.00%
Cabo Rojo	35.11%	63.52%	1.37%	0.00%	0.00%

Caguas	0.00%	0.25%	99.75%	0.00%	0.00%
Camuy	56.16%	40.03%	3.70%	0.11%	0.00%
Canovanas	0.00%	0.00%	96.55%	3.45%	0.00%
Cantano	0.00%	0.00%	96.20%	3.80%	0.00%
Carolina	0.00%	14.50%	85.50%	0.00%	0.00%
Cayey	0.00%	0.99%	98.51%	0.49%	0.00%
Ceiba	8.81%	29.64%	61.55%	0.00%	0.00%
Ciales	6.67%	18.80%	74.53%	0.00%	0.00%
Cidra	0.09%	81.42%	18.49%	0.00%	0.00%
Coamo	71.51%	25.58%	2.91%	0.00%	0.00%
Comerio	1.48%	93.06%	5.46%	0.00%	0.00%
Corozal	16.20%	42.76%	41.04%	0.00%	0.00%
Culebra	4.89%	95.11%	0.00%	0.00%	0.00%
Dorado	0.00%	95.41%	4.59%	0.00%	0.00%
Fajardo	7.39%	33.79%	58.82%	0.00%	0.00%
Florida	0.00%	66.85%	33.15%	0.00%	0.00%
Guanica	55.70%	42.27%	2.02%	0.00%	0.00%
Guayama	0.00%	51.08%	48.83%	0.09%	0.00%
Guayanilla	79.84%	20.16%	0.00%	0.00%	0.00%
Guaynabo	0.00%	83.97%	16.03%	0.00%	0.00%
Gurabo	0.00%	0.00%	64.73%	35.27%	0.00%
Hatillo	25.48%	46.89%	27.63%	0.00%	0.00%
Hormigueros	6.37%	93.40%	0.23%	0.00%	0.00%
Humacao	18.05%	23.81%	58.13%	0.00%	0.00%
Isabela	0.00%	13.16%	86.74%	0.10%	0.00%
Jayuya	33.44%	25.71%	40.49%	0.36%	0.00%
Juana Diaz	0.19%	7.67%	91.73%	0.42%	0.00%
Juncos	0.00%	4.92%	89.53%	5.54%	0.00%
Lajas	2.10%	51.97%	45.93%	0.00%	0.00%
Lares	21.85%	47.87%	20.84%	9.44%	0.00%
Las Marias	0.00%	2.44%	30.22%	41.77%	25.57%
Las Piedras	0.00%	26.14%	73.86%	0.00%	0.00%
Loiza	0.00%	34.88%	65.12%	0.00%	0.00%
Luquillo	0.56%	39.52%	59.92%	0.00%	0.00%
Manati	0.00%	27.73%	72.27%	0.00%	0.00%
Maricao	0.00%	19.06%	80.86%	0.09%	0.00%
Maunabo	0.00%	0.00%	100.00%	0.00%	0.00%
Mayaguez	29.20%	5.18%	16.67%	32.25%	16.70%
Moca	0.00%	0.00%	81.32%	15.25%	3.43%
Morovis	9.12%	31.58%	59.30%	0.00%	0.00%
Naguabo	0.00%	0.75%	99.25%	0.00%	0.00%
Naranjito	11.97%	80.84%	7.19%	0.00%	0.00%

Orocovis	0.43%	67.46%	31.42%	0.69%	0.00%
Patillas	0.01%	0.33%	78.57%	21.09%	0.00%
Penuelas	12.87%	26.30%	60.82%	0.00%	0.00%
Ponce	0.89%	5.18%	93.38%	0.55%	0.00%
Quebradillas	0.37%	43.06%	56.27%	0.31%	0.00%
Rjo Grande	0.00%	0.60%	99.40%	0.00%	0.00%
Rincon	10.37%	43.77%	45.85%	0.00%	0.00%
Sabana Grande	0.00%	47.17%	52.83%	0.00%	0.00%
Salinas	0.16%	83.52%	16.32%	0.00%	0.00%
San German	40.82%	33.16%	26.02%	0.00%	0.00%
San Juan	0.00%	65.30%	34.70%	0.00%	0.00%
San Lorenzo	0.00%	36.69%	54.95%	8.35%	0.00%
San Sebastian	0.06%	2.83%	7.59%	20.15%	69.38%
Santa Isabel	0.97%	70.64%	28.40%	0.00%	0.00%
Toa Alta	0.00%	97.20%	2.80%	0.00%	0.00%
Toa Baja	0.00%	79.85%	20.15%	0.00%	0.00%
Trujillo Alto	0.00%	37.19%	52.99%	9.83%	0.00%
Utuado	67.90%	30.62%	1.48%	0.00%	0.00%
Vega Alta	0.00%	5.60%	94.40%	0.00%	0.00%
Vega Baja	0.00%	0.06%	99.94%	0.00%	0.00%
Vieques	0.00%	24.16%	75.84%	0.00%	0.00%
Villalba	0.00%	22.89%	77.11%	0.00%	0.00%
Yabucoa	0.00%	36.52%	59.37%	4.11%	0.00%
Yauco	24.15%	68.66%	7.19%	0.00%	0.00%

Table 18: Percent of (Island) Hexagonal Area by Severe Storm Hazard Frequency per Municipio

Municipio	Severe Storm Percent Area by Total (Island) Land Area				
	Low (<.05 events)	Medium Low (.05 - .1 events)	Medium (.1 - .2 events)	Medium High (.2 - .3 events)	High (.3 - .5 events)
Adjuntas	6.28%	0.00%	0.11%	0.00%	0.00%
Aguada	0.00%	0.00%	1.78%	1.84%	0.00%
Aguadilla	0.00%	0.00%	2.26%	0.11%	0.00%
Aguas Buenas	0.00%	0.00%	1.33%	0.00%	0.00%
Aibonito	5.19%	0.00%	0.02%	0.00%	0.00%
Anasco	0.00%	0.00%	0.93%	11.60%	10.53%
Arecibo	1.80%	0.00%	3.61%	0.00%	0.00%
Arroyo	0.00%	0.00%	0.79%	0.00%	0.00%
Barceloneta	0.00%	0.00%	0.08%	0.00%	0.00%
Barranquitas	6.02%	0.00%	0.00%	0.00%	0.00%
Bayamon	0.00%	0.00%	0.27%	0.00%	0.00%
Cabo Rojo	5.30%	0.00%	0.06%	0.00%	0.00%
Caguas	0.00%	0.00%	3.66%	0.00%	0.00%

Camuy	5.38%	0.00%	0.11%	0.04%	0.00%
Canovanas	0.00%	0.00%	1.98%	0.92%	0.00%
Cantano	0.00%	0.00%	2.82%	1.44%	0.00%
Carolina	0.00%	0.00%	0.27%	0.00%	0.00%
Cayey	0.00%	0.00%	3.18%	0.21%	0.00%
Ceiba	0.55%	0.00%	1.16%	0.00%	0.00%
Ciales	0.92%	0.00%	3.09%	0.00%	0.00%
Cidra	0.01%	0.00%	0.42%	0.00%	0.00%
Coamo	11.52%	0.00%	0.14%	0.00%	0.00%
Comerio	0.09%	0.00%	0.10%	0.00%	0.00%
Corozal	1.42%	0.00%	1.08%	0.00%	0.00%
Culebra	0.13%	0.00%	0.00%	0.00%	0.00%
Dorado	0.00%	0.00%	0.07%	0.00%	0.00%
Fajardo	0.47%	0.00%	1.11%	0.00%	0.00%
Florida	0.00%	0.00%	0.31%	0.00%	0.00%
Guanica	4.49%	0.00%	0.05%	0.00%	0.00%
Guayama	0.00%	0.00%	2.00%	0.05%	0.00%
Guayanilla	7.09%	0.00%	0.00%	0.00%	0.00%
Guaynabo	0.00%	0.00%	0.28%	0.00%	0.00%
Gurabo	0.00%	0.00%	1.14%	8.02%	0.00%
Hatillo	2.20%	0.00%	0.72%	0.00%	0.00%
Hormigueros	0.15%	0.00%	0.00%	0.00%	0.00%
Humacao	1.68%	0.00%	1.63%	0.00%	0.00%
Isabela	0.00%	0.00%	2.98%	0.04%	0.00%
Jayuya	3.07%	0.00%	1.12%	0.13%	0.00%
Juana Diaz	0.02%	0.00%	3.46%	0.20%	0.00%
Juncos	0.00%	0.00%	1.48%	1.19%	0.00%
Lajas	0.27%	0.00%	1.75%	0.00%	0.00%
Lares	2.78%	0.00%	0.80%	4.67%	0.00%
Las Marias	0.00%	0.00%	0.87%	15.60%	13.99%
Las Piedras	0.00%	0.00%	1.55%	0.00%	0.00%
Loiza	0.00%	0.00%	0.83%	0.00%	0.00%
Luquillo	0.03%	0.00%	0.96%	0.00%	0.00%
Manati	0.00%	0.00%	2.10%	0.00%	0.00%
Maricao	0.00%	0.00%	1.84%	0.03%	0.00%
Maunabo	0.00%	0.00%	1.31%	0.00%	0.00%
Mayaguez	4.70%	0.00%	0.81%	20.20%	15.32%
Moca	0.00%	0.00%	2.54%	6.17%	2.03%
Morovis	0.73%	0.00%	1.43%	0.00%	0.00%
Naguabo	0.00%	0.00%	3.20%	0.00%	0.00%
Naranjito	0.69%	0.00%	0.12%	0.00%	0.00%
Orocovis	0.06%	0.00%	1.24%	0.35%	0.00%

Patillas	0.00%	0.00%	2.30%	8.00%	0.00%
Penuelas	1.19%	0.00%	1.69%	0.00%	0.00%
Ponce	0.22%	0.00%	6.78%	0.52%	0.00%
Quebradillas	0.02%	0.00%	0.81%	0.06%	0.00%
Río Grande	0.00%	0.00%	0.89%	0.00%	0.00%
Rincon	1.30%	0.00%	1.73%	0.00%	0.00%
Sabana Grande	0.00%	0.00%	1.17%	0.00%	0.00%
Salinas	0.02%	0.00%	0.71%	0.00%	0.00%
San German	4.59%	0.00%	0.88%	0.00%	0.00%
San Juan	0.00%	0.00%	1.07%	0.00%	0.00%
San Lorenzo	0.00%	0.00%	1.81%	3.57%	0.00%
San Sebastian	0.01%	0.00%	0.34%	11.53%	58.13%
Santa Isabel	0.07%	0.00%	0.61%	0.00%	0.00%
Toa Alta	0.00%	0.00%	0.05%	0.00%	0.00%
Toa Baja	0.00%	0.00%	0.30%	0.00%	0.00%
Trujillo Alto	0.00%	0.00%	0.70%	1.69%	0.00%
Utua	16.13%	0.00%	0.11%	0.00%	0.00%
Vega Alta	0.00%	0.00%	1.62%	0.00%	0.00%
Vega Baja	0.00%	0.00%	2.89%	0.00%	0.00%
Vieques	0.00%	0.00%	2.50%	0.00%	0.00%
Villalba	0.00%	0.00%	1.77%	0.00%	0.00%
Yabucoa	0.00%	0.00%	2.04%	1.83%	0.00%
Yauco	3.43%	0.00%	0.31%	0.00%	0.00%

Table 19: Severe Storm Hazard Scores and Ranks by Municipio

Municipio	Severe Storm Hazard Score (Log Multiplied)		
	Total Score	Standardized Score (0-1)	Rank of Score (1-78)
San Sebastian	10,575.9905	1.0000	1
Mayaguez	3,648.6263	0.3449	2
Las Marias	3,192.0979	0.3017	3
Anasco	2,398.9407	0.2267	4
Moca	692.6825	0.0654	5
Patillas	429.9594	0.0405	6
Gurabo	413.9245	0.0390	7
Lares	248.4782	0.0234	8
San Lorenzo	206.7745	0.0194	9
Ponce	126.7889	0.0119	10
Yabucoa	124.1260	0.0116	11
Aguada	117.2069	0.0110	12
Cantano	113.1789	0.0106	13
Trujillo Alto	95.2469	0.0089	14

Juncos	80.7070	0.0075	15
Canovanas	74.4881	0.0069	16
Arecibo	63.3328	0.0059	17
Juana Diaz	61.8052	0.0057	18
Cayey	57.1671	0.0053	19
Caguas	53.9661	0.0050	20
Ciales	47.6588	0.0044	21
Isabela	47.4188	0.0044	21
Naguabo	47.2061	0.0043	23
Orocovis	42.9951	0.0040	24
Vega Baja	42.6846	0.0039	25
Aguadilla	39.0161	0.0036	26
Vieques	39.0613	0.0036	26
Guayama	37.4511	0.0034	28
Manati	33.1364	0.0030	29
Lajas	31.1218	0.0028	30
Maricao	29.5223	0.0027	31
Rincon	30.0355	0.0027	31
Villalba	27.5551	0.0025	33
Penuelas	26.9532	0.0024	34
Humacao	25.8939	0.0023	35
Jayuya	24.9660	0.0022	36
Las Piedras	24.3905	0.0022	36
Vega Alta	24.2323	0.0022	36
Morovis	23.2200	0.0021	39
Aguas Buenas	21.0339	0.0019	40
San Juan	21.1129	0.0019	40
Sabana Grande	20.1455	0.0018	42
Salinas	20.1993	0.0018	42
Corozal	19.1122	0.0017	44
Maunabo	19.3065	0.0017	44
Ceiba	18.6464	0.0016	46
Fajardo	18.1730	0.0016	46
Luquillo	15.8852	0.0014	48
Quebradillas	16.4306	0.0014	48
San German	16.2746	0.0014	48
Hatillo	13.9830	0.0012	51
Loiza	13.4336	0.0012	51
Rjo Grande	13.1091	0.0011	53
Santa Isabel	13.0538	0.0011	53
Yauco	12.6028	0.0011	53
Arroyo	12.0840	0.0010	56

Bayamon	10.7016	0.0009	57
Cidra	11.1079	0.0009	57
Cabo Rojo	8.9676	0.0007	59
Utua	8.4211	0.0007	59
Adjuntas	7.8321	0.0006	61
Guaynabo	7.9513	0.0006	61
Toa Baja	7.5512	0.0006	61
Camuy	6.9609	0.0005	64
Coamo	6.1087	0.0005	64
Florida	6.3114	0.0005	64
Comerio	5.8458	0.0004	67
Naranjito	5.5998	0.0004	67
Toa Alta	5.1611	0.0004	67
Barceloneta	4.1016	0.0003	70
Carolina	4.1021	0.0003	70
Dorado	4.6986	0.0003	70
Guanica	3.7434	0.0002	73
Culebra	2.1129	0.0001	74
Guayanilla	1.8803	0.0001	74
Hormigueros	1.7947	0.0001	74
Aibonito	1.5841	0.0000	77
Barranquitas	1.2231	0.0000	77

Hurricane Storm Surges

Hazard Overview

A storm surge is an elevated water level that is pushed towards the shore by the force of strong winds that result in the piling up of water. The advancing surge combines with the normal tides, which in extreme cases can increase the normal water height over 20 feet. The storm surge arrives ahead of the storm's actual landfall and the more intense the hurricane is, the sooner the surge arrives. Water rise can be very rapid and can move far inland, posing a serious threat to those who have not yet evacuated flood-prone areas. Debris carried by the waves can also contribute to the devastation. As the storm approaches shore, the greatest storm surge will be to the north of the hurricane eye, in the right-front quadrant of the direction in which the hurricane is moving. Such a surge of high water topped by waves driven by hurricane force winds can be devastating to coastal regions, causing severe beach erosion and property damage along the immediate coast. Storm surge heights, and associated waves, are dependent upon the shape of the continental shelf (narrow or wide) and the depth of the ocean bottom (bathymetry). A narrow shelf, or one that drops steeply from the shoreline and subsequently produces deep water close to the shoreline, tends to produce a lower surge but higher and more powerful storm waves. While disassociated with the Saffir-Simpson Scale, storm surge remains the leading killer of residents along immediate coastal areas.¹⁷

Data and Methods

This assessment utilized Sea, Lake and Overland Surges from Hurricanes (SLOSH) datasets to map storm surge inundation for the conterminous United States provided by National Oceanic and Atmospheric Administration (NOAA) National Storm Surge Hazard Maps.¹⁸ SLOSH is a computerized model that estimates storm surge heights from tropical cyclones using pressure, size, forward speed, and track data to create a model of the wind field which pushes water. In each SLOSH basin or grid, tens of thousands of hypothetical tropical cyclones are simulated, and the potential storm surge are calculated. The model is best used for defining the potential flooding from storm surge for a location from a threatening hurricane, rather than as a predictor of the specific areas that will be inundated during a particular event. In island regions such as Puerto Rico, NOAA has coupled the SLOSH model and the Simulating Waves Nearshore (SWAN) third-generation wave model, developed at Delft University of Technology, to model storm surge and create MEOW and MOM products. For this assessment average Maximum of the Maximum Envelope of High Water (MEOW), or MOM provides a worst-case snapshot for a particular storm category under "perfect" storm conditions.¹⁹ Each MOM considers combinations of forward speed, trajectory, and initial tide level. These products are

¹⁷ Adapted from <https://www.scemd.org/media/1391/sc-hazard-mitigation-plan-2018-update.pdf>

¹⁸ <https://www.nhc.noaa.gov/nationalsurge>

¹⁹ <https://www.nhc.noaa.gov/surge/momOverview.php>

compiled when a SLOSH basin is developed or updated. It should be noted that no single hurricane will produce the regional flooding depicted in the MOMs. Instead, MOMs are intended to capture the worst case high water value at a particular location for hurricane evacuation planning. For this assessment, MOM water depth associated with each hurricane category was calculated for each hex-grid.

Hazard Frequency Analysis Results

Hurricane storm surges, a uniquely coastal phenomena show differential hazardousness across the island. Far eastern municipios, including Isla de Culebra and Vieques Municipio, as well as the eastern coast of the main island are categorized with deeper water depths from storm surge. The northeastern municipios have more land area in storm surge zones for lower category hurricanes, but deeper surge depth for more intense hurricanes (Figure 10 - Figure 14). Still, no coastline is immune from the possibility of hurricane storm surges. For each category storm, the SLOSH model indicates a differing amount of land area inundated to different depths in each municipio (Table 20, Table 24, Table 28, Table 28, Table 32, Table 36). As a result, the percentage of each municipio's land area changes for each SLOSH model run and category storm (Table 21, Table 25, Table 29, Table 33, Table 37). The percent of each municipio's total island-wide land area also changes for different storms (Table 22, Table 26, Table 30, Table 34, Table 38). Finally, a table showing municipio scores and ranks for each category storm surge provides perspective on which areas of the island are more highly threatened by hazardous storm surge conditions (Table 23, Table 27, Table 31, Table 35, Table 39).

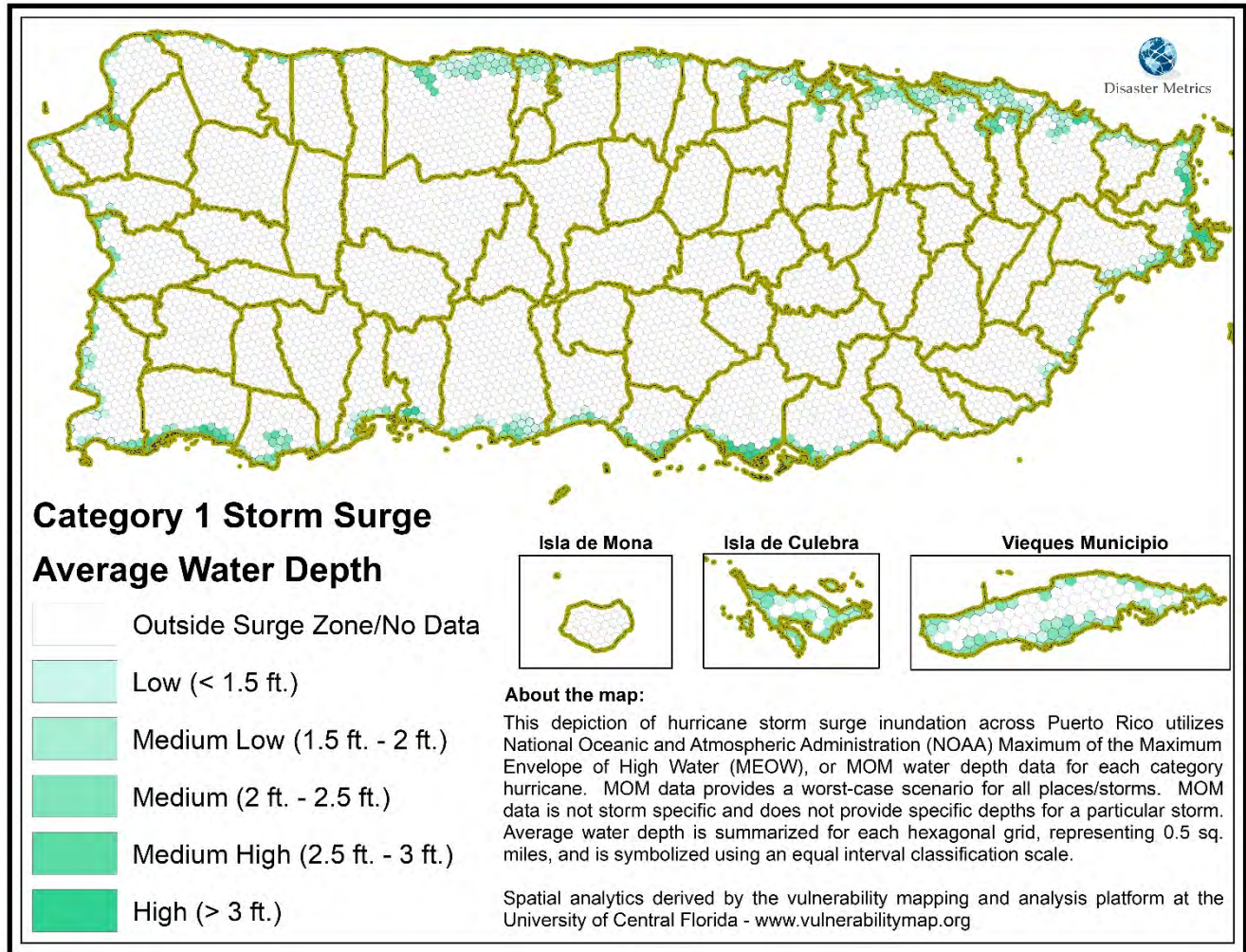


Figure 10: Hurricane Category 1 Storm Surge Hazard Areas

Table 20: Hurricane Category 1 Storm Surge Hazard by Municipio and Areal Extent

Municipio	HEX GRID Area by Category 1 Storm Surge Water Depth (Sq. miles)					
	None	Low (< 1.5 ft.)	Medium Low (1.5 - 2 ft.)	Medium (2 - 2.5 ft.)	Medium High (2.5 - 3 ft.)	High (>3 ft.)
Adjuntas	67.10					
Aguada	27.11		1.27	1.35	1.21	
Aguadilla	31.14	0.50	1.92	1.66	1.33	0.05
Aguas Buenas	30.10					
Aibonito	31.34					
Anasco	37.32	0.15	0.87	0.93	0.28	
Arecibo	107.71	5.78	9.31	2.17	2.00	
Arroyo	13.41	0.68	0.48	0.48		
Barceloneta	11.41	1.60	4.92	0.83		
Barranquitas	34.28					
Bayamon	42.66	0.18	0.73	0.45	0.50	
Cabo Rojo	57.15	4.24	5.80	3.96	1.88	0.10

Caguas	59.07						
Camuy	44.49	0.43	0.70	0.35	0.39		
Canovanas	27.75	0.94	0.52	1.48	2.31		
Carolina	33.70	4.52	5.78	2.85	0.44		
Catano	0.75	0.55	2.73	1.05			
Cayey	51.96						
Ceiba	19.29	1.79	1.47	4.08	1.24	2.50	
Ciales	66.71						
Cidra	36.46						
Coamo	78.03						
Comerio	28.52						
Corozal	42.58						
Culebra	3.30	0.50	4.90	4.23	0.38		
Dorado	18.48	0.93	2.32	1.69			
Fajardo	21.96	0.00	1.44	2.73	2.41	1.96	
Florida	15.22						
Guanica	29.76	1.38	3.14	3.59	1.14	0.00	
Guayama	57.50		1.74	3.44	2.33	0.85	
Guayanilla	36.47	2.70	2.31	1.50			
Guaynabo	26.55	0.33	0.80	0.08			
Gurabo	28.31						
Hatillo	39.62	0.80	0.91		0.51		
Hormigueros	11.34						
Humacao	39.83	2.05	1.98	1.24			
Isabela	51.71	0.25	1.71	0.56	0.74	0.45	
Jayuya	44.53						
Juana Diaz	56.06	1.85	1.47	0.80	0.55		
Juncos	26.62						
Lajas	52.12		0.80	3.19	2.74	2.51	
Lares	61.64						
Las Marias	46.51						
Las Piedras	33.89						
Loiza	4.16	3.87	9.05	3.20	0.25		
Luquillo	21.60	1.17	2.02	1.07			
Manati	41.50	0.90	3.42	1.00			
Maricao	36.63						
Maunabo	19.63		0.71	0.44	0.31		
Mayaguez	72.70	0.00	1.12	3.45	0.69		
Moca	50.37						
Morovis	38.93						
Naguabo	44.10	3.88	1.33	0.98	0.54	1.05	
Naranjito	27.75						

Orocovis	63.78						
Patillas	44.16	0.65	1.36	1.04			
Penuelas	40.47	1.27	1.85	0.08	0.07	1.01	
Ponce	103.97	5.12	4.33	2.41	1.16		
Quebradillas	21.27	0.38	0.19	0.94	0.36		
Rincon	10.97		2.12	1.28	0.01		
Rio Grande	51.24	3.08	3.10	2.16	0.73	0.50	
Sabana Grande	35.84						
Salinas	60.65		1.64	1.02	2.77	3.99	
San German	54.51						
San Juan	37.57	3.86	4.84	2.68	0.58		
San Lorenzo	53.21						
San Sebastian	71.22						
Santa Isabel	27.47	2.27	1.48	0.80	2.44	0.12	
Toa Alta	27.56						
Toa Baja	16.87	2.97	2.07	1.21	0.68		
Trujillo Alto	21.38						
Utuado	115.07						
Vega Alta	26.83		0.39	0.52			
Vega Baja	41.70	1.99	1.48	1.47			
Vieques	28.31	3.89	10.89	9.42	0.66		
Villalba	37.04						
Yabucoa	51.62	1.50	1.65	0.63			
Yauco	68.37			0.45			
Grand Total	3149.92	68.97	115.08	80.93	33.64	15.09	

Table 21: Percent of (Municipio) Hexagonal Area by Hurricane Category 1 Storm Surge Hazard per Municipio

Municipio	Category 1 Storm Surge Water Depth Percent Area by Total (Municipio) Land Area					
	None	Low (< 1.5 ft.)	Medium Low (1.5 - 2 ft.)	Medium (2 - 2.5 ft.)	Medium High (2.5 - 3 ft.)	High (>3 ft.)
Adjuntas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Aguada	87.65%	0.00%	4.09%	4.35%	3.91%	0.00%
Aguadilla	85.07%	1.36%	5.25%	4.54%	3.65%	0.13%
Aguas Buenas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Aibonito	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Anasco	94.35%	0.38%	2.21%	2.35%	0.71%	0.00%
Arecibo	84.83%	4.55%	7.34%	1.71%	1.58%	0.00%
Arroyo	89.12%	4.52%	3.18%	3.19%	0.00%	0.00%
Barceloneta	60.83%	8.54%	26.22%	4.40%	0.00%	0.00%
Barranquitas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Bayamon	95.83%	0.40%	1.63%	1.01%	1.12%	0.00%

Cabo Rojo	78.16%	5.80%	7.93%	5.41%	2.57%	0.13%
Caguas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Camuy	95.95%	0.93%	1.50%	0.76%	0.85%	0.00%
Canovanas	84.09%	2.84%	1.57%	4.49%	7.01%	0.00%
Carolina	71.25%	9.56%	12.23%	6.02%	0.93%	0.00%
Catano	14.81%	10.82%	53.69%	20.68%	0.00%	0.00%
Cayey	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Ceiba	63.53%	5.89%	4.85%	13.42%	4.08%	8.22%
Ciales	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Cidra	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Coamo	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Comerio	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Corozal	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Culebra	24.80%	3.79%	36.80%	31.80%	2.82%	0.00%
Dorado	78.91%	3.97%	9.92%	7.20%	0.00%	0.00%
Fajardo	71.99%	0.00%	4.72%	8.93%	7.91%	6.44%
Florida	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Guanica	76.29%	3.54%	8.04%	9.20%	2.93%	0.00%
Guayama	87.30%	0.00%	2.64%	5.22%	3.54%	1.30%
Guayanilla	84.84%	6.29%	5.38%	3.49%	0.00%	0.00%
Guaynabo	95.63%	1.19%	2.89%	0.29%	0.00%	0.00%
Gurabo	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Hatillo	94.70%	1.91%	2.18%	0.00%	1.21%	0.00%
Hormigueros	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Humacao	88.32%	4.55%	4.39%	2.74%	0.00%	0.00%
Isabela	93.33%	0.44%	3.08%	1.01%	1.33%	0.81%
Jayuya	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Juana Diaz	92.31%	3.05%	2.42%	1.32%	0.90%	0.00%
Juncos	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lajas	84.94%	0.00%	1.31%	5.20%	4.46%	4.09%
Lares	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Marias	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Piedras	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Loiza	20.28%	18.86%	44.09%	15.58%	1.19%	0.00%
Luquillo	83.51%	4.54%	7.80%	4.14%	0.00%	0.00%
Manati	88.63%	1.92%	7.30%	2.15%	0.00%	0.00%
Maricao	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Maunabo	93.08%	0.00%	3.37%	2.08%	1.48%	0.00%
Mayaguez	93.24%	0.00%	1.44%	4.43%	0.89%	0.00%
Moca	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Morovis	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Naguabo	84.99%	7.48%	2.57%	1.89%	1.04%	2.03%

Naranjito	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Orocovis	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Patillas	93.53%	1.39%	2.88%	2.20%	0.00%	0.00%
Penuelas	90.43%	2.84%	4.13%	0.18%	0.16%	2.26%
Ponce	88.88%	4.38%	3.70%	2.06%	0.99%	0.00%
Quebradillas	91.90%	1.66%	0.82%	4.05%	1.57%	0.00%
Rincon	76.26%	0.00%	14.76%	8.89%	0.08%	0.00%
Rio Grande	84.26%	5.06%	5.10%	3.56%	1.21%	0.82%
Sabana Grande	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Salinas	86.57%	0.00%	2.34%	1.46%	3.95%	5.69%
San German	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
San Juan	75.85%	7.80%	9.76%	5.42%	1.17%	0.00%
San Lorenzo	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
San Sebastian	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Santa Isabel	79.44%	6.55%	4.29%	2.30%	7.07%	0.34%
Toa Alta	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Toa Baja	70.88%	12.47%	8.70%	5.09%	2.85%	0.00%
Trujillo Alto	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Utuado	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Vega Alta	96.72%	0.00%	1.42%	1.86%	0.00%	0.00%
Vega Baja	89.40%	4.26%	3.18%	3.16%	0.00%	0.00%
Vieques	53.24%	7.31%	20.48%	17.72%	1.25%	0.00%
Villalba	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Yabucoa	93.17%	2.70%	2.98%	1.14%	0.00%	0.00%
Yauco	99.35%	0.00%	0.00%	0.65%	0.00%	0.00%

Table 22: Percent of (Island) Hexagonal Area by Hurricane Category 1 Storm Surge Hazard per Municipio

Municipio	Category 1 Storm Surge Water Depth Percent Area by Total (Island) Land Area					
	None	Low (< 1.5 ft.)	Medium Low (1.5 - 2 ft.)	Medium (2 - 2.5 ft.)	Medium High (2.5 - 3 ft.)	High (>3 ft.)
Adjuntas	2.13%	0.00%	0.00%	0.00%	0.00%	0.00%
Aguada	0.86%	0.00%	1.10%	1.66%	3.59%	0.00%
Aguadilla	0.99%	0.72%	1.67%	2.05%	3.97%	0.33%
Aguas Buenas	0.96%	0.00%	0.00%	0.00%	0.00%	0.00%
Aibonito	0.99%	0.00%	0.00%	0.00%	0.00%	0.00%
Anasco	1.18%	0.22%	0.76%	1.15%	0.84%	0.00%
Arecibo	3.42%	8.38%	8.09%	2.68%	5.94%	0.00%
Arroyo	0.43%	0.99%	0.42%	0.59%	0.00%	0.00%
Barceloneta	0.36%	2.32%	4.27%	1.02%	0.00%	0.00%
Barranquitas	1.09%	0.00%	0.00%	0.00%	0.00%	0.00%
Bayamon	1.35%	0.26%	0.63%	0.56%	1.49%	0.00%
Cabo Rojo	1.81%	6.15%	5.04%	4.89%	5.58%	0.63%

Caguas	1.88%	0.00%	0.00%	0.00%	0.00%	0.00%
Camuy	1.41%	0.63%	0.61%	0.44%	1.17%	0.00%
Canovanas	0.88%	1.36%	0.45%	1.83%	6.87%	0.00%
Carolina	1.07%	6.56%	5.03%	3.52%	1.31%	0.00%
Catano	0.02%	0.80%	2.37%	1.30%	0.00%	0.00%
Cayey	1.65%	0.00%	0.00%	0.00%	0.00%	0.00%
Ceiba	0.61%	2.60%	1.28%	5.04%	3.68%	16.56%
Ciales	2.12%	0.00%	0.00%	0.00%	0.00%	0.00%
Cidra	1.16%	0.00%	0.00%	0.00%	0.00%	0.00%
Coamo	2.48%	0.00%	0.00%	0.00%	0.00%	0.00%
Comerio	0.91%	0.00%	0.00%	0.00%	0.00%	0.00%
Corozal	1.35%	0.00%	0.00%	0.00%	0.00%	0.00%
Culebra	0.10%	0.73%	4.26%	5.23%	1.11%	0.00%
Dorado	0.59%	1.35%	2.02%	2.08%	0.00%	0.00%
Fajardo	0.70%	0.00%	1.25%	3.37%	7.18%	13.02%
Florida	0.48%	0.00%	0.00%	0.00%	0.00%	0.00%
Guanica	0.94%	2.00%	2.72%	4.43%	3.40%	0.00%
Guayama	1.83%	0.00%	1.51%	4.25%	6.94%	5.66%
Guayanilla	1.16%	3.92%	2.01%	1.85%	0.00%	0.00%
Guaynabo	0.84%	0.48%	0.70%	0.10%	0.00%	0.00%
Gurabo	0.90%	0.00%	0.00%	0.00%	0.00%	0.00%
Hatillo	1.26%	1.16%	0.79%	0.00%	1.50%	0.00%
Hormigueros	0.36%	0.00%	0.00%	0.00%	0.00%	0.00%
Humacao	1.26%	2.97%	1.72%	1.53%	0.00%	0.00%
Isabela	1.64%	0.36%	1.48%	0.69%	2.20%	2.97%
Jayuya	1.41%	0.00%	0.00%	0.00%	0.00%	0.00%
Juana Diaz	1.78%	2.68%	1.28%	0.99%	1.63%	0.00%
Juncos	0.84%	0.00%	0.00%	0.00%	0.00%	0.00%
Lajas	1.65%	0.00%	0.70%	3.94%	8.13%	16.63%
Lares	1.96%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Marias	1.48%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Piedras	1.08%	0.00%	0.00%	0.00%	0.00%	0.00%
Loiza	0.13%	5.62%	7.87%	3.95%	0.73%	0.00%
Luquillo	0.69%	1.70%	1.75%	1.32%	0.00%	0.00%
Manati	1.32%	1.31%	2.97%	1.24%	0.00%	0.00%
Maricao	1.16%	0.00%	0.00%	0.00%	0.00%	0.00%
Maunabo	0.62%	0.00%	0.62%	0.54%	0.92%	0.00%
Mayaguez	2.31%	0.00%	0.98%	4.27%	2.06%	0.00%
Moca	1.60%	0.00%	0.00%	0.00%	0.00%	0.00%
Morovis	1.24%	0.00%	0.00%	0.00%	0.00%	0.00%
Naguabo	1.40%	5.62%	1.16%	1.21%	1.61%	6.99%
Naranjito	0.88%	0.00%	0.00%	0.00%	0.00%	0.00%

Orocovis	2.02%	0.00%	0.00%	0.00%	0.00%	0.00%
Patillas	1.40%	0.95%	1.18%	1.29%	0.00%	0.00%
Penuelas	1.28%	1.84%	1.61%	0.10%	0.22%	6.70%
Ponce	3.30%	7.43%	3.76%	2.97%	3.44%	0.00%
Quebradillas	0.68%	0.56%	0.16%	1.16%	1.08%	0.00%
Rincon	0.35%	0.00%	1.85%	1.58%	0.04%	0.00%
Rio Grande	1.63%	4.46%	2.70%	2.67%	2.18%	3.31%
Sabana Grande	1.14%	0.00%	0.00%	0.00%	0.00%	0.00%
Salinas	1.93%	0.00%	1.42%	1.26%	8.22%	26.42%
San German	1.73%	0.00%	0.00%	0.00%	0.00%	0.00%
San Juan	1.19%	5.60%	4.20%	3.32%	1.72%	0.00%
San Lorenzo	1.69%	0.00%	0.00%	0.00%	0.00%	0.00%
San Sebastian	2.26%	0.00%	0.00%	0.00%	0.00%	0.00%
Santa Isabel	0.87%	3.29%	1.29%	0.98%	7.26%	0.78%
Toa Alta	0.87%	0.00%	0.00%	0.00%	0.00%	0.00%
Toa Baja	0.54%	4.30%	1.80%	1.50%	2.02%	0.00%
Trujillo Alto	0.68%	0.00%	0.00%	0.00%	0.00%	0.00%
Utuado	3.65%	0.00%	0.00%	0.00%	0.00%	0.00%
Vega Alta	0.85%	0.00%	0.34%	0.64%	0.00%	0.00%
Vega Baja	1.32%	2.88%	1.29%	1.82%	0.00%	0.00%
Vieques	0.90%	5.64%	9.46%	11.64%	1.98%	0.00%
Villalba	1.18%	0.00%	0.00%	0.00%	0.00%	0.00%
Yabucoa	1.64%	2.17%	1.44%	0.78%	0.00%	0.00%
Yauco	2.17%	0.00%	0.00%	0.56%	0.00%	0.00%

Table 23: Category 1 Storm Surge Hazard Scores and Ranks by Municipio

Municipio	Hurricane Category 1 Storm Surge Hazard Score (Log Multiplied)		
	Total Score	Standardized Score (0-1)	Rank of Score (1-78)
Salinas	11,012.3392	1.0000	1
Lajas	7,319.6752	0.6647	2
Ceiba	6,759.7123	0.6138	3
Fajardo	5,832.7770	0.5297	4
Guayama	3,025.3604	0.2747	5
Naguabo	2,851.8917	0.259	6
Penuelas	2,564.5751	0.2329	7
Rio Grande	1,544.3216	0.1402	8
Isabela	1,399.2052	0.1271	9
Santa Isabel	1,190.7419	0.1081	10
Cabo Rojo	965.0713	0.0876	11
Canovanas	852.7585	0.0774	12
Arecibo	755.8573	0.0686	13

Aguadilla	625.7940	0.0568	14
Guanica	455.9592	0.0414	15
Aguada	452.4046	0.0411	16
Ponce	449.2464	0.0408	17
Vieques	351.0842	0.0319	18
Mayaguez	288.3089	0.0262	19
Toa Baja	260.7117	0.0237	20
San Juan	242.3464	0.022	21
Juana Diaz	207.9446	0.0189	22
Carolina	196.1911	0.0178	23
Bayamon	186.2984	0.0169	24
Culebra	185.1242	0.0168	25
Hatillo	183.7600	0.0167	26
Camuy	146.7445	0.0133	27
Quebradillas	141.4283	0.0128	28
Loiza	131.6589	0.012	29
Maunabo	117.8503	0.0107	30
Anasco	112.3745	0.0102	31
Dorado	20.1756	0.0018	32
Rincon	19.8531	0.0018	32
Guayanilla	18.5028	0.0017	34
Vega Baja	17.3384	0.0016	35
Humacao	15.2985	0.0014	36
Manati	13.9547	0.0013	37
Barceloneta	13.5590	0.0012	38
Catano	13.7595	0.0012	38
Luquillo	13.4212	0.0012	38
Patillas	12.3980	0.0011	41
Yabucoa	8.4954	0.0008	42
Arroyo	5.6453	0.0005	43
Vega Alta	5.8366	0.0005	43
Yauco	4.7742	0.0004	45
Guaynabo	1.6606	0.0002	46
Adjuntas	0.0000	0.0000	47
Aguas Buenas	0.0000	0.0000	47
Aibonito	0.0000	0.0000	47
Barranquitas	0.0000	0.0000	47
Caguas	0.0000	0.0000	47
Cayey	0.0000	0.0000	47
Ciales	0.0000	0.0000	47
Cidra	0.0000	0.0000	47
Coamo	0.0000	0.0000	47

Comerio	0.0000	0.0000	47
Corozal	0.0000	0.0000	47
Florida	0.0000	0.0000	47
Gurabo	0.0000	0.0000	47
Hormigueros	0.0000	0.0000	47
Jayuya	0.0000	0.0000	47
Juncos	0.0000	0.0000	47
Lares	0.0000	0.0000	47
Las Marias	0.0000	0.0000	47
Las Piedras	0.0000	0.0000	47
Maricao	0.0000	0.0000	47
Moca	0.0000	0.0000	47
Morovis	0.0000	0.0000	47
Naranjito	0.0000	0.0000	47
Orocovis	0.0000	0.0000	47
Sabana Grande	0.0000	0.0000	47
San German	0.0000	0.0000	47
San Lorenzo	0.0000	0.0000	47
San Sebastian	0.0000	0.0000	47
Toa Alta	0.0000	0.0000	47
Trujillo Alto	0.0000	0.0000	47
Utado	0.0000	0.0000	47
Villalba	0.0000	0.0000	47

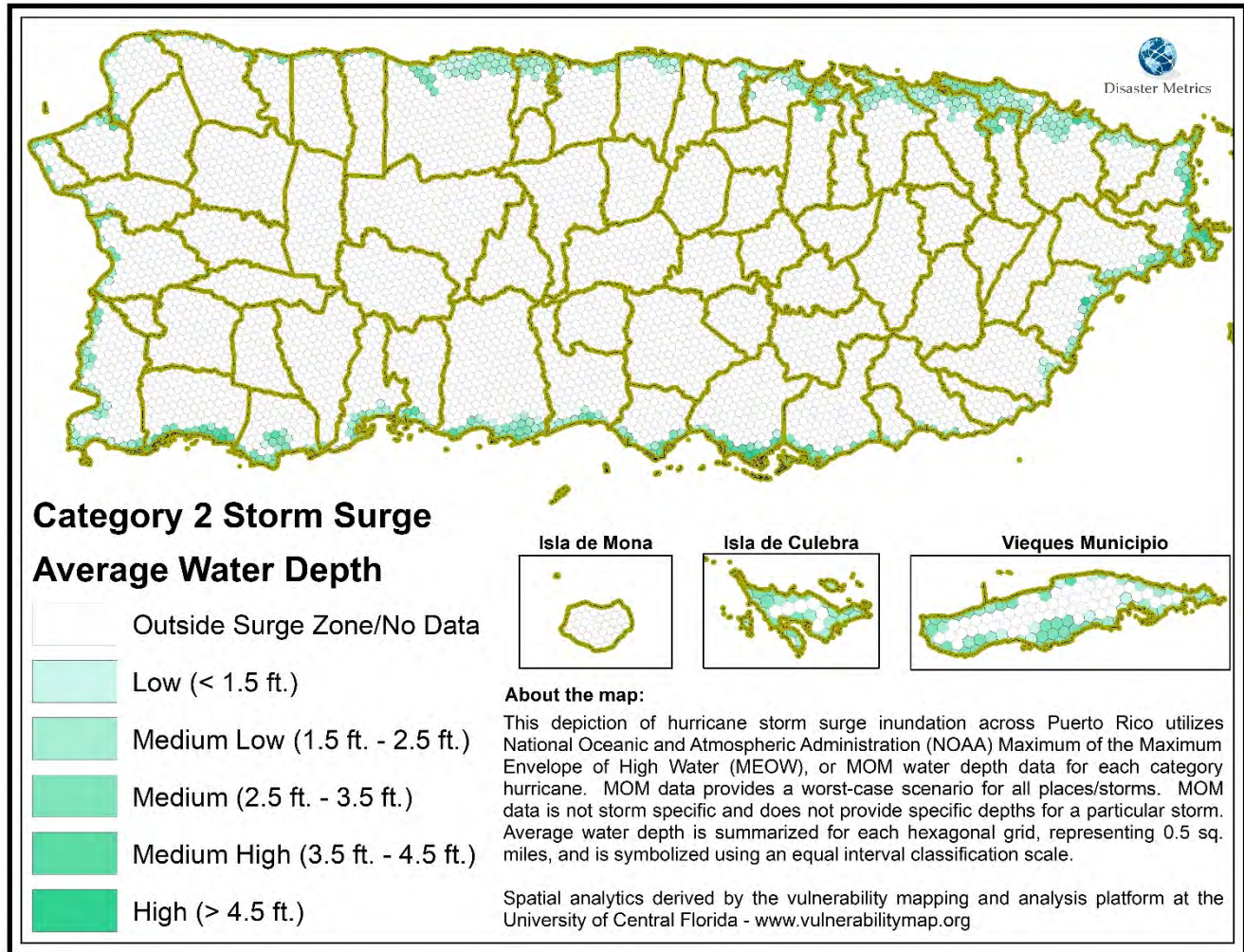


Figure 11: Hurricane Category 2 Storm Surge Hazard Areas

Table 24: Hurricane Category 2 Storm Surge Hazard by Municipio and Areal Extent

Municipio	HEX GRID Area by Category 2 Storm Surge Water Depth (Sq. miles)					
	None	Low (< 1.5 ft.)	Medium Low (1.5 - 2.5 ft.)	Medium (2.5 - 3.5 ft.)	Medium High (3.5 - 4.5 ft.)	High (> 4.5 ft.)
Adjuntas	67.10					
Aguada	27.11		2.26	0.87	0.69	
Aguadilla	31.14		2.90	1.75	0.81	
Aguas Buenas	30.10					
Aibonito	31.34					
Anasco	36.83	0.49	1.03	0.92	0.28	
Arecibo	107.23	4.88	11.66	3.20		
Arroyo	13.41		0.76	0.88		
Barceloneta	11.41	0.51	5.95	0.89		
Barranquitas	34.28					
Bayamon	42.66	0.18	0.23	0.50	0.95	

Cabo Rojo	53.98	2.67	11.33	4.39	0.56	0.19
Caguas	59.07					
Camuy	44.49	0.08	1.40	0.39		
Canovanas	27.75	0.41	0.77	3.45	0.62	
Carolina	32.36	3.34	8.60	2.62	0.38	
Catano	0.25	0.99	2.49	1.30	0.05	
Cayey	51.96					
Ceiba	19.29		2.05	5.74	1.89	1.40
Ciales	66.71					
Cidra	36.46					
Coamo	78.03					
Comerio	28.52					
Corozal	42.58					
Culebra	3.30	0.00	6.38	3.63		
Dorado	18.08	1.28	2.66	1.40		
Fajardo	21.96		1.98	4.30	1.52	0.74
Florida	15.22					
Guanica	28.76	1.17	2.70	5.67	0.71	
Guayama	57.50		0.77	4.54	2.70	0.35
Guayanilla	35.66	0.86	4.22	2.25		
Guaynabo	26.04	0.81	0.83	0.08		
Gurabo	28.31					
Hatillo	39.62		1.50	0.72		
Hormigueros	11.34					
Humacao	36.59	0.86	4.95	2.20		0.50
Isabela	51.21	0.56	2.34	0.96	0.34	
Jayuya	44.53					
Juana Diaz	55.06	0.53	3.92	0.72	0.50	
Juncos	26.62					
Lajas	52.12		0.95	2.11	4.81	1.37
Lares	61.64					
Las Marias	46.51					
Las Piedras	33.89					
Loiza	2.01	3.35	9.15	6.03		
Luquillo	20.60	0.50	4.55	0.21		
Manati	41.00	1.00	3.58	1.24		
Maricao	36.63					
Maunabo	19.63		0.35	1.11		
Mayaguez	72.20	0.93	2.00	2.63	0.22	
Moca	50.37					
Morovis	38.93					
Naguabo	44.07		4.54	2.08	0.88	0.31

Naranjito	27.75						
Orocovis	63.78						
Patillas	44.16		1.81	1.24			
Penuelas	40.47		3.07	0.11	1.11		
Ponce	102.47	1.51	5.31	6.54	1.16		
Quebradillas	21.27	0.00	1.01	0.70	0.16		
Rincon	10.97		1.60	1.81			
Rio Grande	47.74	3.41	7.51	1.42	0.23	0.50	
Sabana Grande	35.84						
Salinas	59.65	1.00	1.03	2.42	3.98	1.98	
San German	54.51						
San Juan	36.66	1.10	9.70	2.07			
San Lorenzo	53.21						
San Sebastian	71.22						
Santa Isabel	27.47	0.47	2.84	2.13	1.55	0.12	
Toa Alta	27.56						
Toa Baja	15.77	1.25	4.66	2.12			
Trujillo Alto	21.38						
Utua	115.07						
Vega Alta	26.79	0.04	0.39	0.52			
Vega Baja	40.24	2.45	2.48	1.47			
Vieques	26.93	4.01	10.58	11.19	0.47		
Villalba	37.04						
Yabucoa	51.12	1.49	2.28	0.52			
Yauco	68.37	0.02		0.43			
Grand Total	3120.88	42.11	163.09	103.50	26.58	7.46	

Table 25: Percent of (Municipio) Hexagonal Area by Hurricane Category 2 Storm Surge Hazard per Municipio

Municipio	Category 2 Storm Surge Water Depth Percent Area by Total (Municipio) Land Area					
	None	Low (< 1.5 ft.)	Medium Low (1.5 - 2.5 ft.)	Medium (2.5 - 3.5 ft.)	Medium High (3.5 - 4.5 ft.)	High (> 4.5 ft.)
Adjuntas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Aguada	87.65%	0.00%	7.31%	2.81%	2.22%	0.00%
Aguadilla	85.07%	0.00%	7.92%	4.79%	2.22%	0.00%
Aguas Buenas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Aibonito	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Anasco	93.10%	1.25%	2.61%	2.33%	0.71%	0.00%
Arecibo	84.45%	3.84%	9.19%	2.52%	0.00%	0.00%
Arroyo	89.12%	0.00%	5.03%	5.85%	0.00%	0.00%
Barceloneta	60.83%	2.69%	31.73%	4.75%	0.00%	0.00%
Barranquitas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Bayamon	95.83%	0.40%	0.51%	1.13%	2.12%	0.00%

Cabo Rojo	73.82%	3.65%	15.50%	6.01%	0.77%	0.25%
Caguas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Camuy	95.95%	0.17%	3.03%	0.85%	0.00%	0.00%
Canovanas	84.09%	1.23%	2.35%	10.47%	1.87%	0.00%
Carolina	68.42%	7.06%	18.18%	5.54%	0.81%	0.00%
Catano	4.97%	19.48%	48.97%	25.49%	1.08%	0.00%
Cayey	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Ceiba	63.53%	0.00%	6.75%	18.89%	6.23%	4.60%
Ciales	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Cidra	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Coamo	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Comerio	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Corozal	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Culebra	24.79%	0.01%	47.95%	27.25%	0.00%	0.00%
Dorado	77.20%	5.47%	11.34%	5.98%	0.00%	0.00%
Fajardo	71.99%	0.00%	6.50%	14.11%	5.00%	2.41%
Florida	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Guanica	73.73%	2.99%	6.93%	14.54%	1.81%	0.00%
Guayama	87.30%	0.00%	1.17%	6.90%	4.09%	0.54%
Guayanilla	82.95%	2.01%	9.81%	5.23%	0.00%	0.00%
Guaynabo	93.77%	2.93%	3.00%	0.29%	0.00%	0.00%
Gurabo	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Hatillo	94.70%	0.00%	3.58%	1.72%	0.00%	0.00%
Hormigueros	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Humacao	81.13%	1.90%	10.98%	4.88%	0.00%	1.11%
Isabela	92.43%	1.00%	4.22%	1.73%	0.62%	0.00%
Jayuya	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Juana Diaz	90.67%	0.87%	6.45%	1.19%	0.82%	0.00%
Juncos	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lajas	84.94%	0.00%	1.56%	3.44%	7.84%	2.23%
Lares	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Marias	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Piedras	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Loiza	9.77%	16.30%	44.56%	29.37%	0.00%	0.00%
Luquillo	79.65%	1.93%	17.61%	0.81%	0.00%	0.00%
Manati	87.56%	2.14%	7.65%	2.65%	0.00%	0.00%
Maricao	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Maunabo	93.08%	0.00%	1.67%	5.25%	0.00%	0.00%
Mayaguez	92.59%	1.19%	2.56%	3.38%	0.28%	0.00%
Moca	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Morovis	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Naguabo	84.95%	0.00%	8.75%	4.01%	1.69%	0.60%

Naranjito	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Orocovis	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Patillas	93.53%	0.00%	3.84%	2.63%	0.00%	0.00%
Penuelas	90.43%	0.00%	6.85%	0.24%	2.48%	0.00%
Ponce	87.59%	1.29%	4.54%	5.59%	0.99%	0.00%
Quebradillas	91.90%	0.01%	4.38%	3.03%	0.68%	0.00%
Rincon	76.26%	0.00%	11.13%	12.61%	0.00%	0.00%
Rio Grande	78.50%	5.60%	12.35%	2.34%	0.38%	0.82%
Sabana Grande	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Salinas	85.14%	1.43%	1.46%	3.45%	5.68%	2.83%
San German	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
San Juan	74.02%	2.22%	19.59%	4.18%	0.00%	0.00%
San Lorenzo	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
San Sebastian	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Santa Isabel	79.44%	1.35%	8.22%	6.16%	4.49%	0.34%
Toa Alta	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Toa Baja	66.27%	5.26%	19.59%	8.89%	0.00%	0.00%
Trujillo Alto	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Utua	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Vega Alta	96.57%	0.15%	1.42%	1.86%	0.00%	0.00%
Vega Baja	86.27%	5.24%	5.33%	3.16%	0.00%	0.00%
Vieques	50.64%	7.53%	19.89%	21.05%	0.89%	0.00%
Villalba	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Yabucoa	92.27%	2.68%	4.11%	0.94%	0.00%	0.00%
Yauco	99.35%	0.02%	0.00%	0.63%	0.00%	0.00%

Table 26: Percent of (Island) Hexagonal Area by Hurricane Category 1 Storm Surge Hazard per Municipio

Municipio	Category 2 Storm Surge Water Depth Percent Area by Total (Island) Land Area					
	None	Low (< 1.5 ft.)	Medium Low (1.5 - 2.5 ft.)	Medium (2.5 - 3.5 ft.)	Medium High (3.5 - 4.5 ft.)	High (> 4.5 ft.)
Adjuntas	2.15%	0.00%	0.00%	0.00%	0.00%	0.00%
Aguada	0.87%	0.00%	1.39%	0.84%	2.58%	0.00%
Aguadilla	1.00%	0.00%	1.78%	1.69%	3.06%	0.00%
Aguas Buenas	0.96%	0.00%	0.00%	0.00%	0.00%	0.00%
Aibonito	1.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Anasco	1.18%	1.17%	0.63%	0.89%	1.06%	0.00%
Arecibo	3.44%	11.59%	7.15%	3.10%	0.00%	0.00%
Arroyo	0.43%	0.00%	0.46%	0.85%	0.00%	0.00%
Barceloneta	0.37%	1.20%	3.65%	0.86%	0.00%	0.00%
Barranquitas	1.10%	0.00%	0.00%	0.00%	0.00%	0.00%
Bayamon	1.37%	0.43%	0.14%	0.49%	3.56%	0.00%
Cabo Rojo	1.73%	6.34%	6.95%	4.24%	2.13%	2.50%

Caguas	1.89%	0.00%	0.00%	0.00%	0.00%	0.00%
Camuy	1.43%	0.19%	0.86%	0.38%	0.00%	0.00%
Canovanas	0.89%	0.96%	0.48%	3.34%	2.32%	0.00%
Carolina	1.04%	7.93%	5.27%	2.53%	1.44%	0.00%
Catano	0.01%	2.35%	1.53%	1.25%	0.21%	0.00%
Cayey	1.66%	0.00%	0.00%	0.00%	0.00%	0.00%
Ceiba	0.62%	0.00%	1.26%	5.54%	7.12%	18.75%
Ciales	2.14%	0.00%	0.00%	0.00%	0.00%	0.00%
Cidra	1.17%	0.00%	0.00%	0.00%	0.00%	0.00%
Coamo	2.50%	0.00%	0.00%	0.00%	0.00%	0.00%
Comerio	0.91%	0.00%	0.00%	0.00%	0.00%	0.00%
Corozal	1.36%	0.00%	0.00%	0.00%	0.00%	0.00%
Culebra	0.11%	0.00%	3.91%	3.50%	0.00%	0.00%
Dorado	0.58%	3.04%	1.63%	1.35%	0.00%	0.00%
Fajardo	0.70%	0.00%	1.22%	4.16%	5.74%	9.86%
Florida	0.49%	0.00%	0.00%	0.00%	0.00%	0.00%
Guanica	0.92%	2.77%	1.66%	5.48%	2.66%	0.00%
Guayama	1.84%	0.00%	0.47%	4.39%	10.14%	4.75%
Guayanilla	1.14%	2.05%	2.59%	2.17%	0.00%	0.00%
Guaynabo	0.83%	1.93%	0.51%	0.08%	0.00%	0.00%
Gurabo	0.91%	0.00%	0.00%	0.00%	0.00%	0.00%
Hatillo	1.27%	0.00%	0.92%	0.70%	0.00%	0.00%
Hormigueros	0.36%	0.00%	0.00%	0.00%	0.00%	0.00%
Humacao	1.17%	2.04%	3.04%	2.13%	0.00%	6.71%
Isabela	1.64%	1.32%	1.43%	0.92%	1.29%	0.00%
Jayuya	1.43%	0.00%	0.00%	0.00%	0.00%	0.00%
Juana Diaz	1.76%	1.25%	2.40%	0.70%	1.88%	0.00%
Juncos	0.85%	0.00%	0.00%	0.00%	0.00%	0.00%
Lajas	1.67%	0.00%	0.59%	2.04%	18.09%	18.34%
Lares	1.98%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Marias	1.49%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Piedras	1.09%	0.00%	0.00%	0.00%	0.00%	0.00%
Loiza	0.06%	7.95%	5.61%	5.83%	0.00%	0.00%
Luquillo	0.66%	1.19%	2.79%	0.20%	0.00%	0.00%
Manati	1.31%	2.38%	2.20%	1.20%	0.00%	0.00%
Maricao	1.17%	0.00%	0.00%	0.00%	0.00%	0.00%
Maunabo	0.63%	0.00%	0.22%	1.07%	0.00%	0.00%
Mayaguez	2.31%	2.20%	1.22%	2.54%	0.82%	0.00%
Moca	1.61%	0.00%	0.00%	0.00%	0.00%	0.00%
Morovis	1.25%	0.00%	0.00%	0.00%	0.00%	0.00%
Naguabo	1.41%	0.00%	2.78%	2.01%	3.30%	4.19%
Naranjito	0.89%	0.00%	0.00%	0.00%	0.00%	0.00%

Orocovis	2.04%	0.00%	0.00%	0.00%	0.00%	0.00%
Patillas	1.42%	0.00%	1.11%	1.20%	0.00%	0.00%
Penuelas	1.30%	0.00%	1.88%	0.10%	4.18%	0.00%
Ponce	3.28%	3.58%	3.26%	6.32%	4.36%	0.00%
Quebradillas	0.68%	0.01%	0.62%	0.68%	0.59%	0.00%
Rincon	0.35%	0.00%	0.98%	1.75%	0.00%	0.00%
Rio Grande	1.53%	8.09%	4.60%	1.38%	0.88%	6.70%
Sabana Grande	1.15%	0.00%	0.00%	0.00%	0.00%	0.00%
Salinas	1.91%	2.37%	0.63%	2.34%	14.98%	26.62%
San German	1.75%	0.00%	0.00%	0.00%	0.00%	0.00%
San Juan	1.17%	2.61%	5.95%	2.00%	0.00%	0.00%
San Lorenzo	1.70%	0.00%	0.00%	0.00%	0.00%	0.00%
San Sebastian	2.28%	0.00%	0.00%	0.00%	0.00%	0.00%
Santa Isabel	0.88%	1.11%	1.74%	2.06%	5.84%	1.59%
Toa Alta	0.88%	0.00%	0.00%	0.00%	0.00%	0.00%
Toa Baja	0.51%	2.97%	2.86%	2.04%	0.00%	0.00%
Trujillo Alto	0.69%	0.00%	0.00%	0.00%	0.00%	0.00%
Utuado	3.69%	0.00%	0.00%	0.00%	0.00%	0.00%
Vega Alta	0.86%	0.10%	0.24%	0.50%	0.00%	0.00%
Vega Baja	1.29%	5.81%	1.52%	1.42%	0.00%	0.00%
Vieques	0.86%	9.51%	6.49%	10.82%	1.78%	0.00%
Villalba	1.19%	0.00%	0.00%	0.00%	0.00%	0.00%
Yabucoa	1.64%	3.53%	1.40%	0.50%	0.00%	0.00%
Yauco	2.19%	0.04%	0.00%	0.42%	0.00%	0.00%

Table 27: Category 2 Storm Surge Hazard Scores and Ranks by Municipio

Municipio	Hurricane Category 2 Storm Surge Hazard Score (Log Multiplied)		
	Total Score	Standardized Score (0-1)	Rank of Score (1-78)
Salinas	10,850.3746	1.0000	1
Lajas	7,910.4827	0.7291	2
Ceiba	7,490.4817	0.6903	3
Fajardo	4,060.5159	0.3742	4
Rio Grande	2,583.9722	0.2381	5
Humacao	2,543.0197	0.2344	6
Guayama	2,386.8035	0.22	7
Naguabo	1,779.2064	0.164	8
Cabo Rojo	1,106.0364	0.1019	9
Santa Isabel	940.0166	0.0866	10
Ponce	304.0644	0.028	11
Penuelas	234.6822	0.0216	12
Vieques	208.5049	0.0192	13

Bayamon	201.2286	0.0185	14
Guanica	200.2752	0.0185	14
Aguadilla	187.1568	0.0172	16
Canovanas	159.8593	0.0147	17
Aguada	152.5667	0.0141	18
Juana Diaz	113.8662	0.0105	19
Carolina	111.1162	0.0102	20
Isabela	82.1409	0.0076	21
Mayaguez	70.9130	0.0065	22
Anasco	67.6849	0.0062	23
Loiza	62.3984	0.0058	24
Arecibo	39.6148	0.0037	25
Quebradillas	39.6068	0.0037	25
Culebra	37.8577	0.0035	27
San Juan	27.0163	0.0025	28
Catano	25.3399	0.0023	29
Guayanilla	23.8670	0.0022	30
Toa Baja	23.1510	0.0021	31
Rincon	17.5813	0.0016	32
Vega Baja	15.7903	0.0015	33
Dorado	15.0554	0.0014	34
Manati	14.3757	0.0013	35
Barceloneta	13.1580	0.0012	36
Patillas	12.6497	0.0012	36
Maunabo	10.1910	0.0009	38
Arroyo	8.5102	0.0008	39
Hatillo	7.7264	0.0007	40
Yabucoa	6.9036	0.0006	41
Luquillo	5.8746	0.0005	42
Vega Alta	4.9550	0.0005	42
Camuy	4.7339	0.0004	44
Yauco	3.8798	0.0004	44
Guaynabo	1.6100	0.0001	46
Adjuntas	0.0000	0.0000	47
Aguas Buenas	0.0000	0.0000	47
Aibonito	0.0000	0.0000	47
Barranquitas	0.0000	0.0000	47
Caguas	0.0000	0.0000	47
Cayey	0.0000	0.0000	47
Ciales	0.0000	0.0000	47
Cidra	0.0000	0.0000	47
Coamo	0.0000	0.0000	47

Comerio	0.0000	0.0000	47
Corozal	0.0000	0.0000	47
Florida	0.0000	0.0000	47
Gurabo	0.0000	0.0000	47
Hormigueros	0.0000	0.0000	47
Jayuya	0.0000	0.0000	47
Juncos	0.0000	0.0000	47
Lares	0.0000	0.0000	47
Las Marias	0.0000	0.0000	47
Las Piedras	0.0000	0.0000	47
Maricao	0.0000	0.0000	47
Moca	0.0000	0.0000	47
Morovis	0.0000	0.0000	47
Naranjito	0.0000	0.0000	47
Orocovis	0.0000	0.0000	47
Sabana Grande	0.0000	0.0000	47
San German	0.0000	0.0000	47
San Lorenzo	0.0000	0.0000	47
San Sebastian	0.0000	0.0000	47
Toa Alta	0.0000	0.0000	47
Trujillo Alto	0.0000	0.0000	47
Utado	0.0000	0.0000	47
Villalba	0.0000	0.0000	47

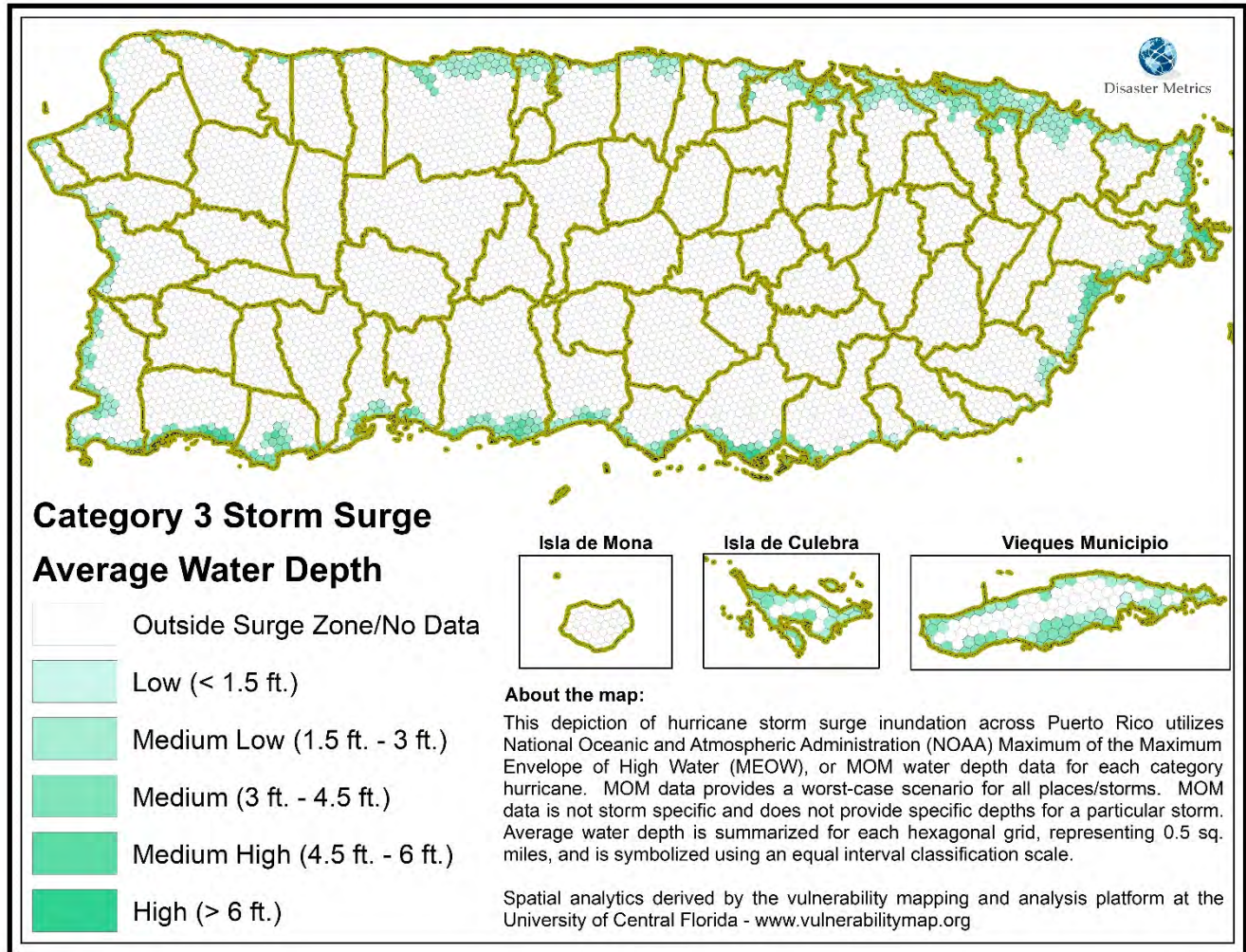


Figure 12: Hurricane Category 3 Storm Surge Hazard Areas

Table 28: Hurricane Category 3 Storm Surge Hazard by Municipio and Areal Extent

Municipio	HEX GRID Area by Category 3 Storm Surge Water Depth (Sq. miles)					
	None	Low (< 1.5 ft.)	Medium Low (1.5 - 3 ft.)	Medium (3 - 4.5 ft.)	Medium High (4.5 - 6 ft.)	High (> 6 ft.)
Adjuntas	67.10					
Aguada	27.11		2.28	1.34	0.20	
Aguadilla	31.14		4.09	0.58	0.80	
Aguas Buenas	30.10					
Aibonito	31.34					
Anasco	36.33	1.42	1.44	0.37		
Arecibo	107.23	1.48	15.17	3.09		
Arroyo	12.53	0.88	1.64			
Barceloneta	11.41	0.50	6.85			
Barranquitas	34.28					
Bayamon	41.76	0.90	0.41	0.50	0.95	
Cabo Rojo	50.52	1.00	12.77	8.08	0.72	0.03

Caguas	59.07						
Camuy	44.49		1.23	0.64			
Canovanas	27.75		1.06	3.33	0.87		
Carolina	32.36	1.00	8.87	5.04	0.03		
Catano	0.25	0.50	3.16	1.12	0.05		
Cayey	51.96						
Ceiba	18.79		3.39	4.16	2.63	1.40	
Ciales	66.71						
Cidra	36.46						
Coamo	78.03						
Comerio	28.52						
Corozal	42.58						
Culebra	3.30	0.00	5.50	4.51			
Dorado	17.41	0.94	3.65	1.42			
Fajardo	21.46		1.83	4.95	2.05	0.21	
Florida	15.22						
Guanica	27.76	0.50	2.17	7.88	0.71		
Guayama	57.50		0.95	4.62	2.80		
Guayanilla	35.16	0.31	4.50	2.72	0.30		
Guaynabo	25.99	0.53	1.02	0.22			
Gurabo	28.31						
Hatillo	39.62		2.11	0.11			
Hormigueros	11.34						
Humacao	32.20	0.89	4.83	3.50	3.68		
Isabela	51.21	0.50	2.42	1.28			
Jayuya	44.53						
Juana Diaz	54.06	0.50	4.03	1.45	0.68		
Juncos	26.62						
Lajas	52.12		0.95	2.45	4.84	1.00	
Lares	61.64						
Las Marias	46.51						
Las Piedras	33.89						
Loiza	1.01	1.00	10.40	7.53	0.60		
Luquillo	20.10	0.50	3.89	1.37			
Manati	41.00	1.00	4.82				
Maricao	36.63						
Maunabo	19.63		0.35	1.11			
Mayaguez	71.31	1.34	2.00	3.32			
Moca	50.37						
Morovis	38.93						
Naguabo	42.47	1.61	3.14	1.74	2.94		
Naranjito	27.75						

Orocovis	63.78						
Patillas	44.04	0.12	2.04	1.01			
Penuelas	40.47		2.86	0.76	0.66		
Ponce	100.97	0.50	5.12	7.74	2.65		
Quebradillas	21.27		1.22	0.65			
Rincon	10.97		2.22	1.19			
Rio Grande	46.74	0.50	10.57	2.27	0.23	0.50	
Sabana Grande	35.84						
Salinas	59.15		2.53	2.84	3.52	2.02	
San German	54.51						
San Juan	35.66	1.53	11.39	0.94			
San Lorenzo	53.21						
San Sebastian	71.22						
Santa Isabel	27.47		2.93	2.82	1.25	0.10	
Toa Alta	27.56						
Toa Baja	14.89	0.95	5.59	2.38			
Trujillo Alto	21.38						
Utuado	115.07						
Vega Alta	26.79	0.04	0.39	0.52			
Vega Baja	39.24	1.95	4.02	1.43			
Vieques	24.93	1.38	13.97	12.89	0.01		
Villalba	37.04						
Yabucoa	50.12	0.50	4.38	0.40			
Yauco	68.37		0.02	0.43			
Grand Total	3093.54	24.78	190.17	116.71	33.18	5.26	

Table 29: Percent of (Municipio) Hexagonal Area by Hurricane Category 3 Storm Surge Hazard per Municipio

Municipio	Category 3 Storm Surge Water Depth Percent Area by Total (Municipio) Land Area					
	None	Low (< 1.5 ft.)	Medium Low (1.5 - 3 ft.)	Medium (3 - 4.5 ft.)	Medium High (4.5 - 6 ft.)	High (> 6 ft.)
Adjuntas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Aguada	87.65%	0.00%	7.36%	4.34%	0.64%	0.00%
Aguadilla	85.07%	0.00%	11.17%	1.57%	2.19%	0.00%
Aguas Buenas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Aibonito	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Anasco	91.83%	3.60%	3.63%	0.94%	0.00%	0.00%
Arecibo	84.45%	1.17%	11.95%	2.44%	0.00%	0.00%
Arroyo	83.29%	5.83%	10.88%	0.00%	0.00%	0.00%
Barceloneta	60.83%	2.67%	36.50%	0.00%	0.00%	0.00%
Barranquitas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Bayamon	93.80%	2.03%	0.91%	1.13%	2.12%	0.00%

Cabo Rojo	69.09%	1.37%	17.46%	11.05%	0.98%	0.04%
Caguas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Camuy	95.95%	0.00%	2.66%	1.39%	0.00%	0.00%
Canovanas	84.09%	0.00%	3.20%	10.08%	2.63%	0.00%
Carolina	68.42%	2.11%	18.76%	10.66%	0.06%	0.00%
Catano	4.97%	9.83%	62.09%	22.02%	1.08%	0.00%
Cayey	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Ceiba	61.88%	0.00%	11.15%	13.70%	8.66%	4.60%
Ciales	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Cidra	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Coamo	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Comerio	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Corozal	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Culebra	24.79%	0.01%	41.33%	33.87%	0.00%	0.00%
Dorado	74.37%	4.01%	15.57%	6.06%	0.00%	0.00%
Fajardo	70.35%	0.00%	6.01%	16.23%	6.72%	0.69%
Florida	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Guanica	71.17%	1.28%	5.55%	20.19%	1.81%	0.00%
Guayama	87.30%	0.00%	1.44%	7.01%	4.25%	0.00%
Guayanilla	81.79%	0.73%	10.47%	6.32%	0.69%	0.00%
Guaynabo	93.61%	1.91%	3.69%	0.79%	0.00%	0.00%
Gurabo	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Hatillo	94.70%	0.00%	5.04%	0.26%	0.00%	0.00%
Hormigueros	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Humacao	71.39%	1.98%	10.71%	7.75%	8.17%	0.00%
Isabela	92.43%	0.90%	4.37%	2.30%	0.00%	0.00%
Jayuya	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Juana Diaz	89.02%	0.82%	6.64%	2.40%	1.12%	0.00%
Juncos	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lajas	84.94%	0.00%	1.56%	3.99%	7.89%	1.62%
Lares	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Marias	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Piedras	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Loiza	4.90%	4.87%	50.64%	36.66%	2.94%	0.00%
Luquillo	77.71%	1.93%	15.04%	5.31%	0.00%	0.00%
Manati	87.56%	2.14%	10.30%	0.00%	0.00%	0.00%
Maricao	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Maunabo	93.08%	0.00%	1.67%	5.25%	0.00%	0.00%
Mayaguez	91.46%	1.72%	2.56%	4.26%	0.00%	0.00%
Moca	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Morovis	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Naguabo	81.85%	3.10%	6.04%	3.35%	5.66%	0.00%

Naranjito	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Orocovis	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Patillas	93.27%	0.26%	4.32%	2.14%	0.00%	0.00%
Penuelas	90.43%	0.00%	6.39%	1.70%	1.48%	0.00%
Ponce	86.31%	0.43%	4.38%	6.62%	2.27%	0.00%
Quebradillas	91.90%	0.00%	5.28%	2.82%	0.00%	0.00%
Rincon	76.26%	0.00%	15.46%	8.28%	0.00%	0.00%
Rio Grande	76.86%	0.82%	17.38%	3.74%	0.38%	0.82%
Sabana Grande	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Salinas	84.43%	0.00%	3.61%	4.05%	5.03%	2.89%
San German	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
San Juan	72.00%	3.08%	23.01%	1.91%	0.00%	0.00%
San Lorenzo	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
San Sebastian	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Santa Isabel	79.44%	0.00%	8.49%	8.17%	3.61%	0.30%
Toa Alta	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Toa Baja	62.54%	3.99%	23.48%	9.99%	0.00%	0.00%
Trujillo Alto	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Utua	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Vega Alta	96.57%	0.15%	1.42%	1.86%	0.00%	0.00%
Vega Baja	84.13%	4.17%	8.63%	3.07%	0.00%	0.00%
Vieques	46.88%	2.60%	26.27%	24.24%	0.02%	0.00%
Villalba	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Yabucoa	90.46%	0.90%	7.91%	0.72%	0.00%	0.00%
Yauco	99.35%	0.00%	0.02%	0.63%	0.00%	0.00%

Table 30: Percent of (Island) Hexagonal Area by Hurricane Category 1 Storm Surge Hazard per Municipio

Municipio	Category 3 Storm Surge Water Depth Percent Area by Total (Island) Land Area					
	None	Low (< 1.5 ft.)	Medium Low (1.5 - 3 ft.)	Medium (3 - 4.5 ft.)	Medium High (4.5 - 6 ft.)	High (> 6 ft.)
Adjuntas	2.17%	0.00%	0.00%	0.00%	0.00%	0.00%
Aguada	0.88%	0.00%	1.20%	1.15%	0.60%	0.00%
Aguadilla	1.01%	0.00%	2.15%	0.49%	2.41%	0.00%
Aguas Buenas	0.97%	0.00%	0.00%	0.00%	0.00%	0.00%
Aibonito	1.01%	0.00%	0.00%	0.00%	0.00%	0.00%
Anasco	1.17%	5.75%	0.75%	0.32%	0.00%	0.00%
Arecibo	3.47%	5.99%	7.98%	2.65%	0.00%	0.00%
Arroyo	0.41%	3.54%	0.86%	0.00%	0.00%	0.00%
Barceloneta	0.37%	2.02%	3.60%	0.00%	0.00%	0.00%
Barranquitas	1.11%	0.00%	0.00%	0.00%	0.00%	0.00%
Bayamon	1.35%	3.64%	0.21%	0.43%	2.85%	0.00%
Cabo Rojo	1.63%	4.04%	6.72%	6.92%	2.17%	0.61%

Caguas	1.91%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Camuy	1.44%	0.00%	0.65%	0.55%	0.00%	0.00%	0.00%
Canovanas	0.90%	0.00%	0.55%	2.85%	2.62%	0.00%	0.00%
Carolina	1.05%	4.02%	4.67%	4.32%	0.08%	0.00%	0.00%
Catano	0.01%	2.02%	1.66%	0.96%	0.17%	0.00%	0.00%
Cayey	1.68%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Ceiba	0.61%	0.00%	1.78%	3.57%	7.93%	26.58%	0.00%
Ciales	2.16%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Cidra	1.18%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Coamo	2.52%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Comerio	0.92%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Corozal	1.38%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Culebra	0.11%	0.01%	2.89%	3.86%	0.00%	0.00%	0.00%
Dorado	0.56%	3.79%	1.92%	1.22%	0.00%	0.00%	0.00%
Fajardo	0.69%	0.00%	0.96%	4.24%	6.18%	3.98%	0.00%
Florida	0.49%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Guanica	0.90%	2.02%	1.14%	6.75%	2.13%	0.00%	0.00%
Guayama	1.86%	0.00%	0.50%	3.96%	8.44%	0.00%	0.00%
Guayanilla	1.14%	1.27%	2.37%	2.33%	0.90%	0.00%	0.00%
Guaynabo	0.84%	2.14%	0.54%	0.19%	0.00%	0.00%	0.00%
Gurabo	0.92%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Hatillo	1.28%	0.00%	1.11%	0.09%	0.00%	0.00%	0.00%
Hormigueros	0.37%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Humacao	1.04%	3.61%	2.54%	2.99%	11.11%	0.00%	0.00%
Isabela	1.66%	2.01%	1.27%	1.09%	0.00%	0.00%	0.00%
Jayuya	1.44%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Juana Diaz	1.75%	2.02%	2.12%	1.25%	2.05%	0.00%	0.00%
Juncos	0.86%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lajas	1.68%	0.00%	0.50%	2.10%	14.60%	18.93%	0.00%
Lares	1.99%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Marias	1.50%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Piedras	1.10%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Loiza	0.03%	4.04%	5.47%	6.45%	1.82%	0.00%	0.00%
Luquillo	0.65%	2.02%	2.04%	1.18%	0.00%	0.00%	0.00%
Manati	1.33%	4.04%	2.54%	0.00%	0.00%	0.00%	0.00%
Maricao	1.18%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Maunabo	0.63%	0.00%	0.19%	0.95%	0.00%	0.00%	0.00%
Mayaguez	2.31%	5.41%	1.05%	2.85%	0.00%	0.00%	0.00%
Moca	1.63%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Morovis	1.26%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Naguabo	1.37%	6.48%	1.65%	1.49%	8.85%	0.00%	0.00%
Naranjito	0.90%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Orocovis	2.06%	0.00%	0.00%	0.00%	0.00%	0.00%
Patillas	1.42%	0.50%	1.07%	0.87%	0.00%	0.00%
Penuelas	1.31%	0.00%	1.50%	0.65%	2.00%	0.00%
Ponce	3.26%	2.02%	2.69%	6.63%	8.00%	0.00%
Quebradillas	0.69%	0.00%	0.64%	0.56%	0.00%	0.00%
Rincon	0.35%	0.00%	1.17%	1.02%	0.00%	0.00%
Rio Grande	1.51%	2.02%	5.56%	1.95%	0.70%	9.49%
Sabana Grande	1.16%	0.00%	0.00%	0.00%	0.00%	0.00%
Salinas	1.91%	0.00%	1.33%	2.43%	10.62%	38.46%
San German	1.76%	0.00%	0.00%	0.00%	0.00%	0.00%
San Juan	1.15%	6.17%	5.99%	0.81%	0.00%	0.00%
San Lorenzo	1.72%	0.00%	0.00%	0.00%	0.00%	0.00%
San Sebastian	2.30%	0.00%	0.00%	0.00%	0.00%	0.00%
Santa Isabel	0.89%	0.00%	1.54%	2.42%	3.76%	1.95%
Toa Alta	0.89%	0.00%	0.00%	0.00%	0.00%	0.00%
Toa Baja	0.48%	3.83%	2.94%	2.04%	0.00%	0.00%
Trujillo Alto	0.69%	0.00%	0.00%	0.00%	0.00%	0.00%
Utuado	3.72%	0.00%	0.00%	0.00%	0.00%	0.00%
Vega Alta	0.87%	0.17%	0.21%	0.44%	0.00%	0.00%
Vega Baja	1.27%	7.85%	2.12%	1.23%	0.00%	0.00%
Vieques	0.81%	5.58%	7.35%	11.05%	0.03%	0.00%
Villalba	1.20%	0.00%	0.00%	0.00%	0.00%	0.00%
Yabucoa	1.62%	2.02%	2.30%	0.34%	0.00%	0.00%
Yauco	2.21%	0.00%	0.01%	0.37%	0.00%	0.00%

Table 31: Category 3 Storm Surge Hazard Scores and Ranks by Municipio

Municipio	Hurricane Category 3 Storm Surge Hazard Score (Log Multiplied)		
	Total Score	Standardized Score (0-1)	Rank of Score (1-78)
Salinas	10751.3595	1.0000	1
Ceiba	7490.0536	0.6967	2
Lajas	5941.8171	0.5527	3
Rio Grande	2541.5848	0.2364	4
Fajardo	1497.0050	0.1392	5
Humacao	791.7419	0.0736	6
Santa Isabel	788.0859	0.0733	7
Naguabo	622.8731	0.0579	8
Guayama	614.4716	0.0572	9
Ponce	611.5413	0.0569	10
Cabo Rojo	379.3554	0.0353	11
Guanica	208.8471	0.0194	12
Canovanas	206.0455	0.0192	13

Bayamon	199.8185	0.0186	14
Loiza	190.4136	0.0177	15
Aguadilla	172.5707	0.0161	16
Juana Diaz	154.3210	0.0144	17
Penuelas	144.9914	0.0135	18
Vieques	111.6481	0.0104	19
Guayanilla	85.5961	0.008	20
Aguada	53.0239	0.0049	21
Carolina	51.0750	0.0048	22
Culebra	38.5943	0.0036	23
Arecibo	34.7651	0.0032	24
Mayaguez	27.7639	0.0026	25
Catano	22.3714	0.0021	26
Toa Baja	22.6181	0.0021	26
San Juan	15.6241	0.0015	28
Vega Baja	14.7693	0.0014	29
Dorado	13.8890	0.0013	30
Luquillo	13.4820	0.0013	30
Isabela	11.7550	0.0011	32
Rincon	10.7056	0.001	33
Patillas	9.2597	0.0009	34
Maunabo	8.8204	0.0008	35
Yabucoa	6.2551	0.0006	36
Camuy	5.8149	0.0005	37
Quebradillas	5.8619	0.0005	37
Anasco	4.5698	0.0004	39
Barceloneta	4.7710	0.0004	39
Vega Alta	4.2834	0.0004	39
Manati	3.6938	0.0003	42
Yauco	3.3771	0.0003	42
Guaynabo	2.6529	0.0002	44
Hatillo	2.2266	0.0002	44
Arroyo	1.5302	0.0001	46
Adjuntas	0.0000	0.0000	47
Aguas Buenas	0.0000	0.0000	47
Aibonito	0.0000	0.0000	47
Barranquitas	0.0000	0.0000	47
Caguas	0.0000	0.0000	47
Cayey	0.0000	0.0000	47
Ciales	0.0000	0.0000	47
Cidra	0.0000	0.0000	47
Coamo	0.0000	0.0000	47

Comerio	0.0000	0.0000	47
Corozal	0.0000	0.0000	47
Florida	0.0000	0.0000	47
Gurabo	0.0000	0.0000	47
Hormigueros	0.0000	0.0000	47
Jayuya	0.0000	0.0000	47
Juncos	0.0000	0.0000	47
Lares	0.0000	0.0000	47
Las Marias	0.0000	0.0000	47
Las Piedras	0.0000	0.0000	47
Maricao	0.0000	0.0000	47
Moca	0.0000	0.0000	47
Morovis	0.0000	0.0000	47
Naranjito	0.0000	0.0000	47
Orocovis	0.0000	0.0000	47
Sabana Grande	0.0000	0.0000	47
San German	0.0000	0.0000	47
San Lorenzo	0.0000	0.0000	47
San Sebastian	0.0000	0.0000	47
Toa Alta	0.0000	0.0000	47
Trujillo Alto	0.0000	0.0000	47
Utado	0.0000	0.0000	47
Villalba	0.0000	0.0000	47

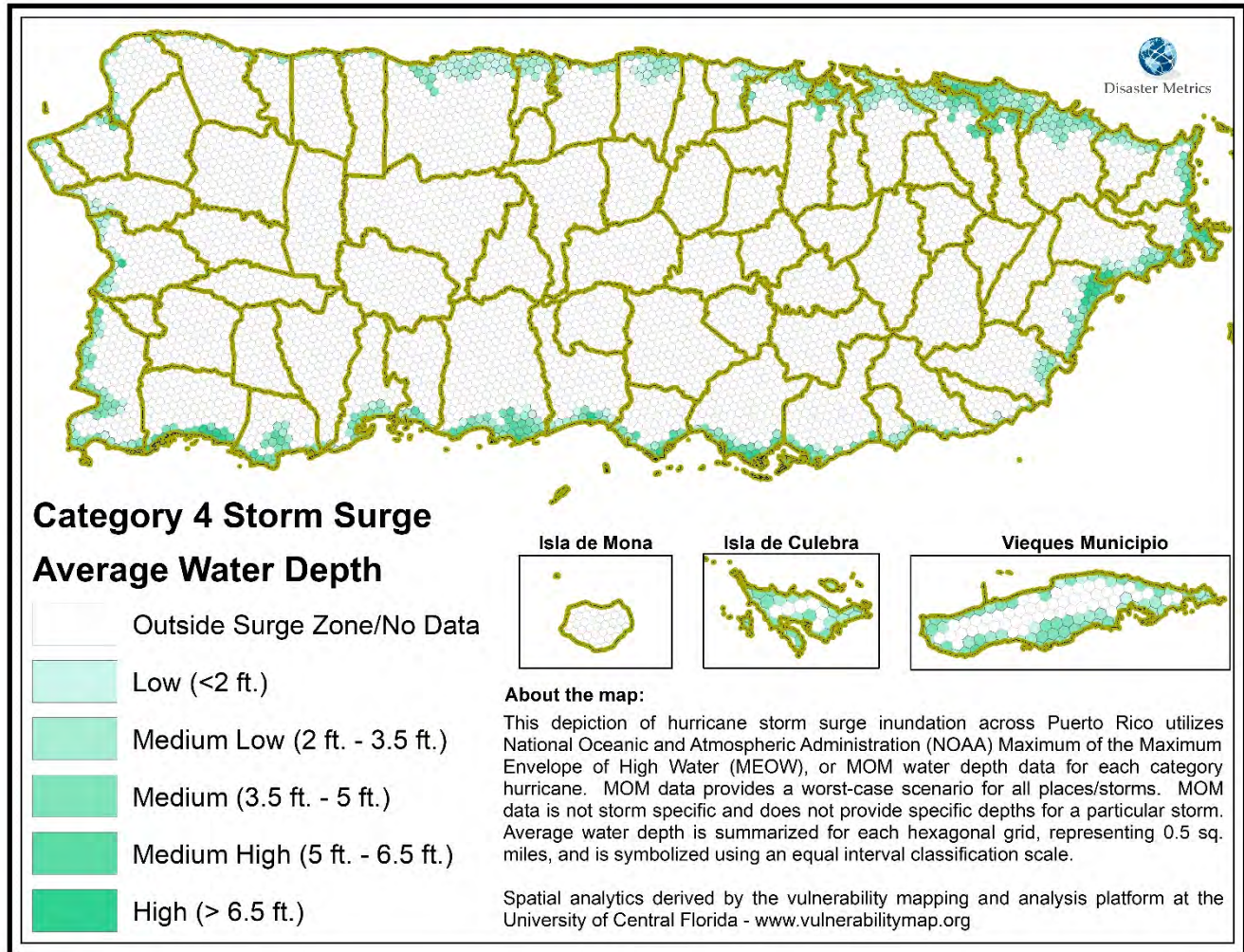


Figure 13: Hurricane Category 4 Storm Surge Hazard Areas

Table 32: Hurricane Category 4 Storm Surge Hazard by Municipio and Areal Extent

Municipio	HEX GRID Area by Category 4 Storm Surge Water Depth (Sq. miles)					
	None	Low (< 2 ft.)	Medium Low (2 - 3.5 ft.)	Medium (3.5 - 5 ft.)	Medium High (5 - 6.5 ft.)	High (> 6.5 ft.)
Adjuntas	67.10					
Aguada	26.92	0.66	2.10	0.56	0.69	
Aguadilla	30.83	0.31	3.45	1.20	0.81	
Aguas Buenas	30.10					
Aibonito	31.34					
Anasco	35.24	2.89	1.05	0.37		
Arecibo	106.19	10.29	7.87	2.63		
Arroyo	11.53	0.98	2.49	0.04		
Barceloneta	11.41	1.43	5.92			
Barranquitas	34.28					
Bayamon	41.72	0.49	0.86	0.95	0.50	
Cabo Rojo	48.40	2.73	8.16	12.42	0.86	0.54

Caguas	59.07					
Camuy	44.49		1.88			
Canovanas	27.75		1.44	0.50	3.31	
Carolina	30.86	2.51	5.99	2.55	4.98	0.41
Catano	0.25		2.56	1.25	1.02	
Cayey	51.96					
Ceiba	18.79	0.50	2.89	2.71	4.03	1.45
Ciales	66.71					
Cidra	36.46					
Coamo	78.03					
Comerio	28.52					
Corozal	42.58					
Culebra	3.30	0.00	5.62	4.39		
Dorado	16.91	1.39	4.21	0.90		
Fajardo	21.46		1.91	4.40	2.01	0.73
Florida	15.22					
Guanica	27.76		2.67	5.96	2.62	0.00
Guayama	57.00	0.50	0.25	4.76	2.70	0.65
Guayanilla	34.39	1.31	1.96	4.83	0.50	
Guaynabo	25.17	1.38	0.90	0.30		
Gurabo	28.31					
Hatillo	39.62		2.22			
Hormigueros	11.34					
Humacao	30.70	1.50	3.50	4.53	1.66	3.22
Isabela	51.21	1.17	2.68	0.34		
Jayuya	44.53					
Juana Diaz	53.56	2.00	1.56	2.66	0.27	0.68
Juncos	26.62					
Lajas	52.12		0.45	1.82	3.39	3.57
Lares	61.64					
Las Marias	46.51					
Las Piedras	33.89					
Loiza	0.35	2.02	5.73	7.20	4.65	0.59
Luquillo	19.02	1.08	3.58	2.18		
Manati	41.00	1.68	4.14			
Maricao	36.63					
Maunabo	18.64	1.05	0.95	0.44		
Mayaguez	68.51	3.71	3.99	1.26		0.50
Moca	50.37					
Morovis	38.93					
Naguabo	39.97	3.00	3.07	2.15	2.10	1.59
Naranjito	27.75					

Orocovis	63.78					
Patillas	43.52	0.51	1.78	1.40		
Penuelas	40.47		2.02	1.54	0.67	0.05
Ponce	98.97	1.50	4.35	5.92	5.82	0.43
Quebradillas	21.27		1.72	0.16		
Rincon	10.60		2.26	1.53		
Rio Grande	44.99	1.25	10.29	3.55	0.73	
Sabana Grande	35.84					
Salinas	58.15	1.50	1.53	3.15	2.83	2.91
San German	54.51					
San Juan	35.51	3.21	9.51	1.29		
San Lorenzo	53.21					
San Sebastian	71.22					
Santa Isabel	26.97		2.31	2.38	1.91	1.01
Toa Alta	27.56					
Toa Baja	14.89	1.71	4.86	2.35		
Trujillo Alto	21.38					
Utuado	115.07					
Vega Alta	26.79	0.04	0.72	0.19		
Vega Baja	35.24	5.45	4.87	1.09		
Vieques	24.52	1.90	12.69	13.73	0.34	
Villalba	37.04					
Yabucoa	48.12	2.00	4.16	1.12		
Yauco	68.14		0.25	0.43		
Grand Total	3060.73	63.68	159.33	113.15	48.40	18.34

Table 33: Percent of (Municipio) Hexagonal Area by Hurricane Category 4 Storm Surge Hazard per Municipio

Municipio	Category 4 Storm Surge Water Depth Percent Area by Total (Municipio) Land Area					
	None	Low (< 2 ft.)	Medium Low (2 - 3.5 ft.)	Medium (3.5 - 5 ft.)	Medium High (5 - 6.5 ft.)	High (> 6.5 ft.)
Adjuntas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Aguada	87.04%	2.15%	6.78%	1.82%	2.22%	0.00%
Aguadilla	84.21%	0.86%	9.43%	3.29%	2.22%	0.00%
Aguas Buenas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Aibonito	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Anasco	89.09%	7.31%	2.66%	0.94%	0.00%	0.00%
Arecibo	83.63%	8.10%	6.20%	2.07%	0.00%	0.00%
Arroyo	76.64%	6.51%	16.55%	0.29%	0.00%	0.00%
Barceloneta	60.83%	7.61%	31.56%	0.00%	0.00%	0.00%
Barranquitas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Bayamon	93.72%	1.09%	1.93%	2.13%	1.12%	0.00%
Cabo Rojo	66.20%	3.74%	11.17%	16.99%	1.18%	0.73%

Caguas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Camuy	95.95%	0.00%	4.05%	0.00%	0.00%	0.00%
Canovanas	84.09%	0.00%	4.37%	1.51%	10.03%	0.00%
Carolina	65.25%	5.31%	12.66%	5.40%	10.53%	0.86%
Catano	4.97%	0.00%	50.30%	24.64%	20.09%	0.00%
Cayey	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Ceiba	61.88%	1.65%	9.51%	8.92%	13.25%	4.79%
Ciales	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Cidra	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Coamo	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Comerio	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Corozal	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Culebra	24.79%	0.01%	42.21%	32.99%	0.00%	0.00%
Dorado	72.23%	5.95%	17.97%	3.85%	0.00%	0.00%
Fajardo	70.35%	0.00%	6.25%	14.41%	6.59%	2.40%
Florida	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Guanica	71.17%	0.00%	6.83%	15.28%	6.72%	0.00%
Guayama	86.54%	0.76%	0.37%	7.23%	4.11%	0.99%
Guayanilla	80.00%	3.06%	4.56%	11.23%	1.15%	0.00%
Guaynabo	90.67%	4.98%	3.26%	1.09%	0.00%	0.00%
Gurabo	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Hatillo	94.70%	0.00%	5.30%	0.00%	0.00%	0.00%
Hormigueros	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Humacao	68.06%	3.33%	7.76%	10.04%	3.67%	7.14%
Isabela	92.43%	2.12%	4.83%	0.62%	0.00%	0.00%
Jayuya	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Juana Diaz	88.20%	3.29%	2.57%	4.37%	0.45%	1.12%
Juncos	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lajas	84.94%	0.00%	0.74%	2.97%	5.53%	5.82%
Lares	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Marias	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Piedras	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Loiza	1.70%	9.83%	27.89%	35.04%	22.66%	2.89%
Luquillo	73.56%	4.19%	13.83%	8.43%	0.00%	0.00%
Manati	87.56%	3.60%	8.84%	0.00%	0.00%	0.00%
Maricao	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Maunabo	88.41%	5.00%	4.51%	2.08%	0.00%	0.00%
Mayaguez	87.87%	4.76%	5.12%	1.61%	0.00%	0.64%
Moca	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Morovis	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Naguabo	77.04%	5.78%	5.92%	4.14%	4.04%	3.07%
Naranjito	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Orocovis	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Patillas	92.18%	1.09%	3.76%	2.96%	0.00%	0.00%
Penuelas	90.43%	0.00%	4.52%	3.45%	1.49%	0.12%
Ponce	84.60%	1.28%	3.71%	5.06%	4.98%	0.36%
Quebradillas	91.90%	0.00%	7.42%	0.68%	0.00%	0.00%
Rincon	73.65%	0.00%	15.70%	10.65%	0.00%	0.00%
Rio Grande	73.98%	2.06%	16.92%	5.84%	1.21%	0.00%
Sabana Grande	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Salinas	83.00%	2.14%	2.18%	4.49%	4.03%	4.15%
San German	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
San Juan	71.71%	6.48%	19.21%	2.61%	0.00%	0.00%
San Lorenzo	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
San Sebastian	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Santa Isabel	78.00%	0.00%	6.68%	6.88%	5.51%	2.93%
Toa Alta	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Toa Baja	62.54%	7.20%	20.40%	9.87%	0.00%	0.00%
Trujillo Alto	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Utuado	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Vega Alta	96.57%	0.15%	2.58%	0.70%	0.00%	0.00%
Vega Baja	75.55%	11.68%	10.44%	2.33%	0.00%	0.00%
Vieques	46.10%	3.58%	23.87%	25.82%	0.63%	0.00%
Villalba	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Yabucoa	86.85%	3.61%	7.51%	2.02%	0.00%	0.00%
Yauco	99.01%	0.00%	0.36%	0.63%	0.00%	0.00%

Table 34: Percent of (Island) Hexagonal Area by Hurricane Category 4 Storm Surge Hazard per Municipio

Municipio	Category 4 Storm Surge Water Depth Percent Area by Total (Island) Land Area					
	None	Low (< 2 ft.)	Medium Low (2 - 3.5 ft.)	Medium (3.5 - 5 ft.)	Medium High (5 - 6.5 ft.)	High (> 6.5 ft.)
Adjuntas	2.19%	0.00%	0.00%	0.00%	0.00%	0.00%
Aguada	0.88%	1.04%	1.32%	0.50%	1.42%	0.00%
Aguadilla	1.01%	0.49%	2.17%	1.06%	1.68%	0.00%
Aguas Buenas	0.98%	0.00%	0.00%	0.00%	0.00%	0.00%
Aibonito	1.02%	0.00%	0.00%	0.00%	0.00%	0.00%
Anasco	1.15%	4.54%	0.66%	0.33%	0.00%	0.00%
Arecibo	3.47%	16.15%	4.94%	2.33%	0.00%	0.00%
Arroyo	0.38%	1.54%	1.56%	0.04%	0.00%	0.00%
Barceloneta	0.37%	2.24%	3.72%	0.00%	0.00%	0.00%
Barranquitas	1.12%	0.00%	0.00%	0.00%	0.00%	0.00%
Bayamon	1.36%	0.76%	0.54%	0.84%	1.03%	0.00%
Cabo Rojo	1.58%	4.29%	5.12%	10.98%	1.78%	2.93%
Caguas	1.93%	0.00%	0.00%	0.00%	0.00%	0.00%

Camuy	1.45%	0.00%	1.18%	0.00%	0.00%	0.00%
Canovanas	0.91%	0.00%	0.90%	0.44%	6.84%	0.00%
Carolina	1.01%	3.94%	3.76%	2.26%	10.29%	2.22%
Catano	0.01%	0.00%	1.60%	1.11%	2.11%	0.00%
Cayey	1.70%	0.00%	0.00%	0.00%	0.00%	0.00%
Ceiba	0.61%	0.79%	1.81%	2.40%	8.32%	7.93%
Ciales	2.18%	0.00%	0.00%	0.00%	0.00%	0.00%
Cidra	1.19%	0.00%	0.00%	0.00%	0.00%	0.00%
Coamo	2.55%	0.00%	0.00%	0.00%	0.00%	0.00%
Comerio	0.93%	0.00%	0.00%	0.00%	0.00%	0.00%
Corozal	1.39%	0.00%	0.00%	0.00%	0.00%	0.00%
Culebra	0.11%	0.00%	3.53%	3.88%	0.00%	0.00%
Dorado	0.55%	2.19%	2.64%	0.80%	0.00%	0.00%
Fajardo	0.70%	0.00%	1.20%	3.89%	4.15%	4.00%
Florida	0.50%	0.00%	0.00%	0.00%	0.00%	0.00%
Guanica	0.91%	0.00%	1.67%	5.27%	5.42%	0.00%
Guayama	1.86%	0.79%	0.15%	4.21%	5.59%	3.55%
Guayanilla	1.12%	2.06%	1.23%	4.27%	1.03%	0.00%
Guaynabo	0.82%	2.17%	0.57%	0.27%	0.00%	0.00%
Gurabo	0.93%	0.00%	0.00%	0.00%	0.00%	0.00%
Hatillo	1.29%	0.00%	1.39%	0.00%	0.00%	0.00%
Hormigueros	0.37%	0.00%	0.00%	0.00%	0.00%	0.00%
Humacao	1.00%	2.36%	2.20%	4.00%	3.42%	17.55%
Isabela	1.67%	1.84%	1.68%	0.30%	0.00%	0.00%
Jayuya	1.46%	0.00%	0.00%	0.00%	0.00%	0.00%
Juana Diaz	1.75%	3.14%	0.98%	2.35%	0.56%	3.70%
Juncos	0.87%	0.00%	0.00%	0.00%	0.00%	0.00%
Lajas	1.70%	0.00%	0.29%	1.61%	7.01%	19.48%
Lares	2.01%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Marias	1.52%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Piedras	1.11%	0.00%	0.00%	0.00%	0.00%	0.00%
Loiza	0.01%	3.17%	3.59%	6.36%	9.61%	3.24%
Luquillo	0.62%	1.70%	2.24%	1.93%	0.00%	0.00%
Manati	1.34%	2.64%	2.60%	0.00%	0.00%	0.00%
Maricao	1.20%	0.00%	0.00%	0.00%	0.00%	0.00%
Maunabo	0.61%	1.66%	0.60%	0.39%	0.00%	0.00%
Mayaguez	2.24%	5.83%	2.50%	1.11%	0.00%	2.73%
Moca	1.65%	0.00%	0.00%	0.00%	0.00%	0.00%
Morovis	1.27%	0.00%	0.00%	0.00%	0.00%	0.00%
Naguabo	1.31%	4.71%	1.93%	1.90%	4.33%	8.69%
Naranjito	0.91%	0.00%	0.00%	0.00%	0.00%	0.00%
Orocovis	2.08%	0.00%	0.00%	0.00%	0.00%	0.00%

Patillas	1.42%	0.81%	1.12%	1.24%	0.00%	0.00%
Penuelas	1.32%	0.00%	1.27%	1.36%	1.37%	0.29%
Ponce	3.23%	2.36%	2.73%	5.23%	12.03%	2.32%
Quebradillas	0.69%	0.00%	1.08%	0.14%	0.00%	0.00%
Rincon	0.35%	0.00%	1.42%	1.35%	0.00%	0.00%
Rio Grande	1.47%	1.96%	6.46%	3.14%	1.52%	0.00%
Sabana Grande	1.17%	0.00%	0.00%	0.00%	0.00%	0.00%
Salinas	1.90%	2.36%	0.96%	2.78%	5.84%	15.87%
San German	1.78%	0.00%	0.00%	0.00%	0.00%	0.00%
San Juan	1.16%	5.04%	5.97%	1.14%	0.00%	0.00%
San Lorenzo	1.74%	0.00%	0.00%	0.00%	0.00%	0.00%
San Sebastian	2.33%	0.00%	0.00%	0.00%	0.00%	0.00%
Santa Isabel	0.88%	0.00%	1.45%	2.10%	3.94%	5.52%
Toa Alta	0.90%	0.00%	0.00%	0.00%	0.00%	0.00%
Toa Baja	0.49%	2.69%	3.05%	2.08%	0.00%	0.00%
Trujillo Alto	0.70%	0.00%	0.00%	0.00%	0.00%	0.00%
Utua	3.76%	0.00%	0.00%	0.00%	0.00%	0.00%
Vega Alta	0.88%	0.06%	0.45%	0.17%	0.00%	0.00%
Vega Baja	1.15%	8.55%	3.06%	0.96%	0.00%	0.00%
Vieques	0.80%	2.99%	7.97%	12.14%	0.70%	0.00%
Villalba	1.21%	0.00%	0.00%	0.00%	0.00%	0.00%
Yabucoa	1.57%	3.14%	2.61%	0.99%	0.00%	0.00%
Yauco	2.23%	0.00%	0.15%	0.38%	0.00%	0.00%

Table 35: Category 4 Storm Surge Hazard Scores and Ranks by Municipio

Municipio	Hurricane Category 4 Storm Surge Hazard Score (Log Multiplied)		
	Total Score	Standardized Score (0-1)	Rank of Score (1-78)
Lajas	10596.3214	1.0000	1
Humacao	9331.2624	0.8806	2
Salinas	8655.4331	0.8168	3
Naguabo	4839.4604	0.4567	4
Ceiba	4784.8214	0.4516	5
Santa Isabel	3178.1529	0.2999	6
Loiza	2517.5095	0.2376	7
Fajardo	2430.6567	0.2294	8
Guayama	2323.8240	0.2193	9
Ponce	2237.8924	0.2112	10
Carolina	2016.3969	0.1903	11
Juana Diaz	1966.5684	0.1856	12
Cabo Rojo	1748.4441	0.165	13
Mayaguez	1412.3602	0.1333	14

Canovanas	573.3036	0.0541	15
Guanica	496.5264	0.0469	16
Penuelas	273.4937	0.0258	17
Catano	186.5175	0.0176	18
Vieques	168.1433	0.0159	19
Rio Grande	160.0585	0.0151	20
Aguadilla	151.0817	0.0143	21
Aguada	123.7794	0.0117	22
Guayanilla	122.0075	0.0115	23
Bayamon	93.4898	0.0088	24
Culebra	36.3921	0.0034	25
Arecibo	26.3630	0.0025	26
Toa Baja	21.0936	0.002	27
Luquillo	18.7889	0.0018	28
San Juan	17.2050	0.0016	29
Rincon	12.9390	0.0012	30
Vega Baja	12.2929	0.0012	30
Patillas	11.6424	0.0011	32
Yabucoa	11.6340	0.0011	32
Dorado	10.0193	0.0009	34
Barceloneta	4.8024	0.0005	35
Anasco	3.8244	0.0004	36
Isabela	4.7262	0.0004	36
Maunabo	4.0413	0.0004	36
Guaynabo	3.0573	0.0003	39
Manati	3.4247	0.0003	39
Yauco	3.3540	0.0003	39
Arroyo	2.3789	0.0002	42
Hatillo	1.7474	0.0002	42
Quebradillas	2.4904	0.0002	42
Vega Alta	1.9817	0.0002	42
Camuy	1.4789	0.0001	46
Adjuntas	0.0000	0.0000	47
Aguas Buenas	0.0000	0.0000	47
Aibonito	0.0000	0.0000	47
Barranquitas	0.0000	0.0000	47
Caguas	0.0000	0.0000	47
Cayey	0.0000	0.0000	47
Ciales	0.0000	0.0000	47
Cidra	0.0000	0.0000	47
Coamo	0.0000	0.0000	47
Comerio	0.0000	0.0000	47

Corozal	0.0000	0.0000	47
Florida	0.0000	0.0000	47
Gurabo	0.0000	0.0000	47
Hormigueros	0.0000	0.0000	47
Jayuya	0.0000	0.0000	47
Juncos	0.0000	0.0000	47
Lares	0.0000	0.0000	47
Las Marias	0.0000	0.0000	47
Las Piedras	0.0000	0.0000	47
Maricao	0.0000	0.0000	47
Moca	0.0000	0.0000	47
Morovis	0.0000	0.0000	47
Naranjito	0.0000	0.0000	47
Orocovis	0.0000	0.0000	47
Sabana Grande	0.0000	0.0000	47
San German	0.0000	0.0000	47
San Lorenzo	0.0000	0.0000	47
San Sebastian	0.0000	0.0000	47
Toa Alta	0.0000	0.0000	47
Trujillo Alto	0.0000	0.0000	47
Utado	0.0000	0.0000	47
Villalba	0.0000	0.0000	47

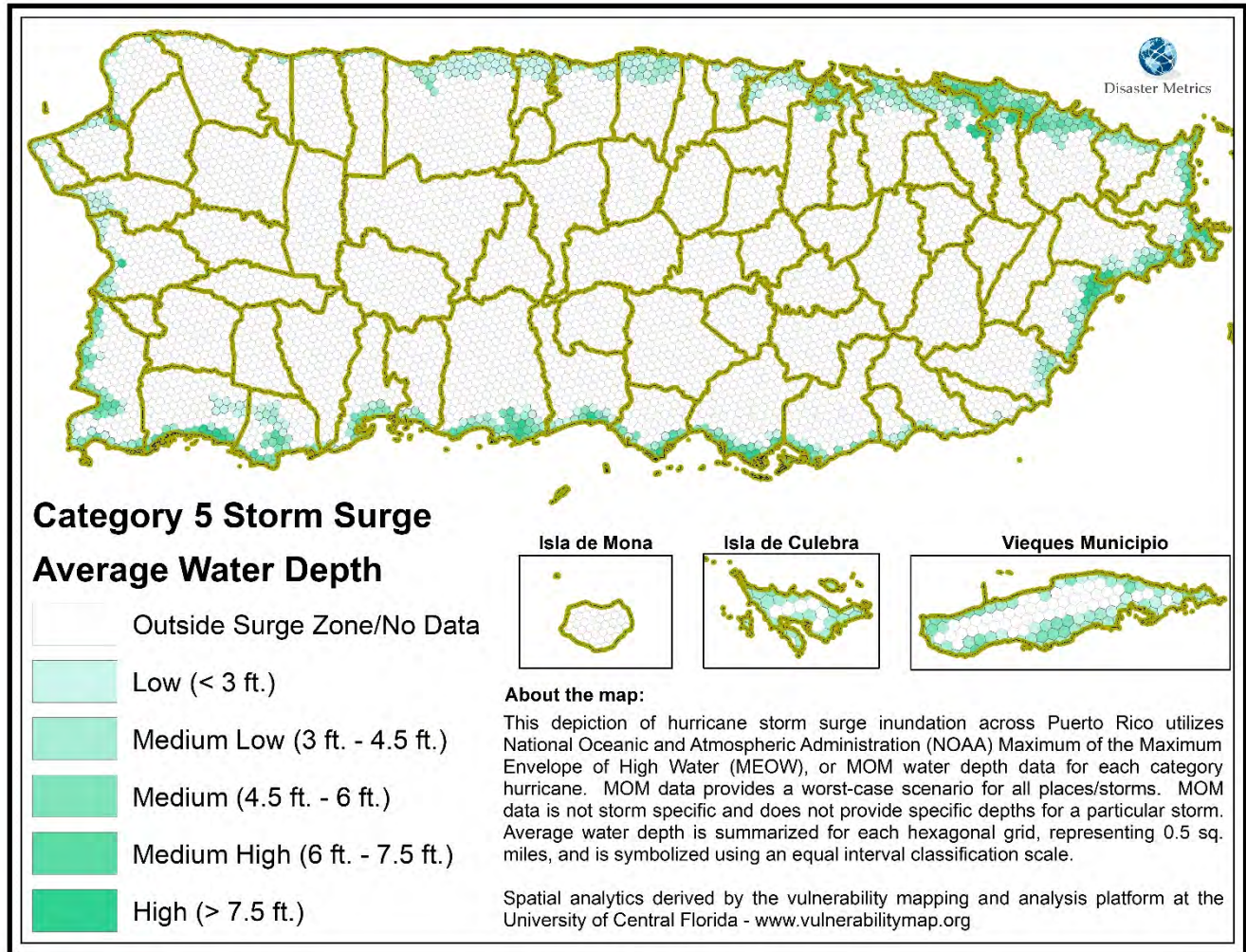


Figure 14: Hurricane Category 5 Storm Surge Hazard Areas

Table 36: Hurricane Category 5 Storm Surge Hazard by Municipio and Areal Extent

Municipio	HEX GRID Area by Category 5 Storm Surge Water Depth (Sq. miles)					
	None	Low (< 3 ft.)	Medium Low (3 - 4.5 ft.)	Medium (4.5 - 6 ft.)	Medium High (6 - 7.5 ft.)	High (> 7.5 ft.)
Adjuntas	67.10					
Aguada	25.92	3.19	0.66	0.96	0.20	
Aguadilla	30.83	1.63	2.99	0.35	0.80	
Aguas Buenas	30.10					
Aibonito	31.34					
Anasco	32.75	5.83	0.98			
Arecibo	106.69	16.18	3.46	0.64		
Arroyo	11.53	2.28	1.24			
Barceloneta	10.91	7.28	0.56			
Barranquitas	34.28					
Bayamon	40.47	0.99	1.13	1.17	0.75	
Cabo Rojo	46.90	4.64	6.85	10.54	3.64	0.54

Caguas	59.07					
Camuy	44.49	0.58	1.30			
Canovanas	26.24	1.39	0.91	1.48	0.84	2.15
Carolina	28.38	4.54	5.41	4.15	1.53	3.29
Catano		0.55	1.91	1.35	1.27	
Cayey	51.96					
Ceiba	17.35	2.17	3.00	2.90	3.38	1.58
Ciales	66.71					
Cidra	36.46					
Coamo	78.03					
Comerio	28.52					
Corozal	42.58					
Culebra	3.30	0.25	9.49	0.27		
Dorado	15.92	5.00	2.18	0.32		
Fajardo	21.41	0.73	1.29	5.30	0.78	1.01
Florida	15.22					
Guanica	22.46	5.30	3.22	5.40	2.62	0.00
Guayama	56.50	1.18	0.77	4.56	1.87	0.98
Guayanilla	34.39	1.31	2.26	4.09	0.65	0.30
Guaynabo	25.53	0.98	0.96	0.30		
Gurabo	28.31					
Hatillo	39.62	0.51	1.71			
Hormigueros	11.34					
Humacao	30.20	2.50	3.10	4.43	1.66	3.22
Isabela	51.21	2.84	1.35			
Jayuya	44.53					
Juana Diaz	53.06	3.00	1.13	2.15	0.71	0.68
Juncos	26.62					
Lajas	46.92	5.20	1.45	0.82	3.15	3.81
Lares	61.64					
Las Marias	46.51					
Las Piedras	33.89					
Loiza	0.35	2.23	2.45	5.61	7.35	2.55
Luquillo	19.02	1.08	4.61	1.15		
Manati	38.63	6.83	1.37			
Maricao	36.63					
Maunabo	18.64	1.81	0.62	0.01		
Mayaguez	68.00	6.88	2.16	0.43		0.50
Moca	50.37					
Morovis	38.93					
Naguabo	38.97	5.32	1.75	2.29	1.96	1.59
Naranjito	27.75					

Orocovis	63.78						
Patillas	43.52	0.67	2.82	0.20			
Penuelas	40.47	0.50	2.02	1.54	0.11	0.11	
Ponce	98.97	2.50	5.00	4.15	4.71	1.66	
Quebradillas	21.27	1.03	0.84				
Rincon	10.60	1.06	2.73				
Rio Grande	44.99	1.59	4.69	6.16	3.39		
Sabana Grande	35.84						
Salinas	57.65	2.50	1.11	2.66	2.64	3.50	
San German	54.51						
San Juan	34.16	7.42	6.47	0.98	0.50		
San Lorenzo	53.21						
San Sebastian	71.22						
Santa Isabel	26.47	0.99	1.35	3.34	1.23	1.19	
Toa Alta	27.56						
Toa Baja	12.39	7.60	3.28	0.54			
Trujillo Alto	21.38						
Utuado	115.07						
Vega Alta	26.29	1.45					
Vega Baja	32.11	7.76	6.36	0.41			
Vieques	23.02	6.59	15.62	7.62	0.34		
Villalba	37.04						
Yabucoa	47.62	3.47	3.40	0.91			
Yauco	68.14		0.68				
Grand Total	3021.73	149.32	128.66	89.16	46.08	28.68	

Table 37: Percent of (Municipio) Hexagonal Area by Hurricane Category 5 Storm Surge Hazard per Municipio

Municipio	Category 5 Storm Surge Water Depth Percent Area by Total (Municipio) Land Area					
	None	Low (< 3 ft.)	Medium Low (3 - 4.5 ft.)	Medium (4.5 - 6 ft.)	Medium High (6 - 7.5 ft.)	High (> 7.5 ft.)
Adjuntas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Aguada	83.80%	10.31%	2.15%	3.10%	0.64%	0.00%
Aguadilla	84.21%	4.47%	8.18%	0.96%	2.19%	0.00%
Aguas Buenas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Aibonito	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Anasco	82.80%	14.73%	2.48%	0.00%	0.00%	0.00%
Arecibo	84.02%	12.74%	2.73%	0.50%	0.00%	0.00%
Arroyo	76.64%	15.13%	8.23%	0.00%	0.00%	0.00%
Barceloneta	58.17%	38.83%	3.00%	0.00%	0.00%	0.00%
Barranquitas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Bayamon	90.92%	2.21%	2.55%	2.64%	1.68%	0.00%
Cabo Rojo	64.15%	6.35%	9.37%	14.42%	4.98%	0.73%

Caguas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Camuy	95.95%	1.25%	2.80%	0.00%	0.00%	0.00%
Canovanas	79.51%	4.20%	2.74%	4.47%	2.56%	6.52%
Carolina	59.99%	9.60%	11.44%	8.76%	3.24%	6.96%
Catano	0.00%	10.88%	37.48%	26.58%	25.06%	0.00%
Cayey	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Ceiba	57.13%	7.13%	9.88%	9.53%	11.12%	5.20%
Ciales	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Cidra	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Coamo	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Comerio	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Corozal	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Culebra	24.79%	1.90%	71.30%	2.02%	0.00%	0.00%
Dorado	67.97%	21.35%	9.32%	1.36%	0.00%	0.00%
Fajardo	70.16%	2.39%	4.22%	17.36%	2.55%	3.32%
Florida	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Guanica	57.58%	13.58%	8.26%	13.85%	6.72%	0.00%
Guayama	85.78%	1.78%	1.18%	6.92%	2.84%	1.49%
Guayanilla	80.00%	3.06%	5.25%	9.50%	1.50%	0.69%
Guaynabo	91.95%	3.52%	3.44%	1.09%	0.00%	0.00%
Gurabo	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Hatillo	94.70%	1.22%	4.09%	0.00%	0.00%	0.00%
Hormigueros	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Humacao	66.95%	5.54%	6.88%	9.82%	3.67%	7.14%
Isabela	92.43%	5.13%	2.44%	0.00%	0.00%	0.00%
Jayuya	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Juana Diaz	87.38%	4.94%	1.86%	3.54%	1.17%	1.12%
Juncos	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lajas	76.46%	8.48%	2.37%	1.34%	5.14%	6.22%
Lares	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Marias	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Piedras	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Loiza	1.70%	10.84%	11.91%	27.33%	35.78%	12.44%
Luquillo	73.56%	4.19%	17.82%	4.43%	0.00%	0.00%
Manati	82.50%	14.58%	2.92%	0.00%	0.00%	0.00%
Maricao	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Maunabo	88.41%	8.60%	2.93%	0.07%	0.00%	0.00%
Mayaguez	87.22%	8.82%	2.77%	0.55%	0.00%	0.64%
Moca	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Morovis	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Naguabo	75.11%	10.26%	3.37%	4.40%	3.78%	3.07%
Naranjito	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Orocovis	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Patillas	92.18%	1.42%	5.97%	0.42%	0.00%	0.00%
Penuelas	90.43%	1.12%	4.52%	3.45%	0.24%	0.25%
Ponce	84.60%	2.14%	4.27%	3.54%	4.02%	1.42%
Quebradillas	91.90%	4.47%	3.63%	0.00%	0.00%	0.00%
Rincon	73.65%	7.35%	19.00%	0.00%	0.00%	0.00%
Rio Grande	73.98%	2.61%	7.71%	10.12%	5.58%	0.00%
Sabana Grande	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Salinas	82.28%	3.57%	1.58%	3.80%	3.77%	5.00%
San German	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
San Juan	68.97%	14.98%	13.06%	1.97%	1.01%	0.00%
San Lorenzo	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
San Sebastian	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Santa Isabel	76.55%	2.87%	3.91%	9.67%	3.57%	3.43%
Toa Alta	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Toa Baja	52.04%	31.91%	13.80%	2.26%	0.00%	0.00%
Trujillo Alto	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Utuado	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Vega Alta	94.77%	5.23%	0.00%	0.00%	0.00%	0.00%
Vega Baja	68.85%	16.64%	13.63%	0.89%	0.00%	0.00%
Vieques	43.28%	12.38%	29.38%	14.33%	0.63%	0.00%
Villalba	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Yabucoa	85.95%	6.27%	6.13%	1.65%	0.00%	0.00%
Yauco	99.01%	0.00%	0.99%	0.00%	0.00%	0.00%

Table 38: Percent of (Island) Hexagonal Area by Hurricane Category 5 Storm Surge Hazard per Municipio

Municipio	Category 5 Storm Surge Water Depth Percent Area by Total (Island) Land Area					
	None	Low (< 3 ft.)	Medium Low (3 - 4.5 ft.)	Medium (4.5 - 6 ft.)	Medium High (6 - 7.5 ft.)	High (> 7.5 ft.)
Adjuntas	2.22%	0.00%	0.00%	0.00%	0.00%	0.00%
Aguada	0.86%	2.13%	0.52%	1.07%	0.43%	0.00%
Aguadilla	1.02%	1.09%	2.33%	0.39%	1.74%	0.00%
Aguas Buenas	1.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Aibonito	1.04%	0.00%	0.00%	0.00%	0.00%	0.00%
Anasco	1.08%	3.90%	0.76%	0.00%	0.00%	0.00%
Arecibo	3.53%	10.84%	2.69%	0.72%	0.00%	0.00%
Arroyo	0.38%	1.52%	0.96%	0.00%	0.00%	0.00%
Barceloneta	0.36%	4.88%	0.44%	0.00%	0.00%	0.00%
Barranquitas	1.13%	0.00%	0.00%	0.00%	0.00%	0.00%
Bayamon	1.34%	0.66%	0.88%	1.32%	1.62%	0.00%
Cabo Rojo	1.55%	3.11%	5.33%	11.82%	7.90%	1.87%
Caguas	1.95%	0.00%	0.00%	0.00%	0.00%	0.00%

Camuy	1.47%	0.39%	1.01%	0.00%	0.00%	0.00%
Canovanas	0.87%	0.93%	0.70%	1.66%	1.83%	7.50%
Carolina	0.94%	3.04%	4.21%	4.65%	3.33%	11.48%
Catano	0.00%	0.37%	1.48%	1.52%	2.77%	0.00%
Cayey	1.72%	0.00%	0.00%	0.00%	0.00%	0.00%
Ceiba	0.57%	1.45%	2.33%	3.25%	7.33%	5.51%
Ciales	2.21%	0.00%	0.00%	0.00%	0.00%	0.00%
Cidra	1.21%	0.00%	0.00%	0.00%	0.00%	0.00%
Coamo	2.58%	0.00%	0.00%	0.00%	0.00%	0.00%
Comerio	0.94%	0.00%	0.00%	0.00%	0.00%	0.00%
Corozal	1.41%	0.00%	0.00%	0.00%	0.00%	0.00%
Culebra	0.11%	0.17%	7.37%	0.30%	0.00%	0.00%
Dorado	0.53%	3.35%	1.70%	0.36%	0.00%	0.00%
Fajardo	0.71%	0.49%	1.00%	5.94%	1.69%	3.53%
Florida	0.50%	0.00%	0.00%	0.00%	0.00%	0.00%
Guanica	0.74%	3.55%	2.50%	6.06%	5.69%	0.00%
Guayama	1.87%	0.79%	0.60%	5.11%	4.06%	3.43%
Guayanilla	1.14%	0.88%	1.76%	4.58%	1.40%	1.04%
Guaynabo	0.84%	0.65%	0.74%	0.34%	0.00%	0.00%
Gurabo	0.94%	0.00%	0.00%	0.00%	0.00%	0.00%
Hatillo	1.31%	0.34%	1.33%	0.00%	0.00%	0.00%
Hormigueros	0.38%	0.00%	0.00%	0.00%	0.00%	0.00%
Humacao	1.00%	1.67%	2.41%	4.97%	3.59%	11.22%
Isabela	1.69%	1.90%	1.05%	0.00%	0.00%	0.00%
Jayuya	1.47%	0.00%	0.00%	0.00%	0.00%	0.00%
Juana Diaz	1.76%	2.01%	0.88%	2.41%	1.54%	2.37%
Juncos	0.88%	0.00%	0.00%	0.00%	0.00%	0.00%
Lajas	1.55%	3.48%	1.13%	0.92%	6.84%	13.30%
Lares	2.04%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Marias	1.54%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Piedras	1.12%	0.00%	0.00%	0.00%	0.00%	0.00%
Loiza	0.01%	1.49%	1.90%	6.29%	15.94%	8.91%
Luquillo	0.63%	0.73%	3.58%	1.28%	0.00%	0.00%
Manati	1.28%	4.57%	1.06%	0.00%	0.00%	0.00%
Maricao	1.21%	0.00%	0.00%	0.00%	0.00%	0.00%
Maunabo	0.62%	1.21%	0.48%	0.02%	0.00%	0.00%
Mayaguez	2.25%	4.61%	1.68%	0.48%	0.00%	1.74%
Moca	1.67%	0.00%	0.00%	0.00%	0.00%	0.00%
Morovis	1.29%	0.00%	0.00%	0.00%	0.00%	0.00%
Naguabo	1.29%	3.57%	1.36%	2.56%	4.26%	5.56%
Naranjito	0.92%	0.00%	0.00%	0.00%	0.00%	0.00%
Orocovis	2.11%	0.00%	0.00%	0.00%	0.00%	0.00%

Patillas	1.44%	0.45%	2.19%	0.22%	0.00%	0.00%
Penuelas	1.34%	0.33%	1.57%	1.73%	0.23%	0.39%
Ponce	3.28%	1.67%	3.88%	4.65%	10.21%	5.80%
Quebradillas	0.70%	0.69%	0.65%	0.00%	0.00%	0.00%
Rincon	0.35%	0.71%	2.13%	0.00%	0.00%	0.00%
Rio Grande	1.49%	1.06%	3.64%	6.90%	7.36%	0.00%
Sabana Grande	1.19%	0.00%	0.00%	0.00%	0.00%	0.00%
Salinas	1.91%	1.67%	0.86%	2.98%	5.73%	12.21%
San German	1.80%	0.00%	0.00%	0.00%	0.00%	0.00%
San Juan	1.13%	4.97%	5.03%	1.09%	1.09%	0.00%
San Lorenzo	1.76%	0.00%	0.00%	0.00%	0.00%	0.00%
San Sebastian	2.36%	0.00%	0.00%	0.00%	0.00%	0.00%
Santa Isabel	0.88%	0.66%	1.05%	3.75%	2.68%	4.14%
Toa Alta	0.91%	0.00%	0.00%	0.00%	0.00%	0.00%
Toa Baja	0.41%	5.09%	2.55%	0.60%	0.00%	0.00%
Trujillo Alto	0.71%	0.00%	0.00%	0.00%	0.00%	0.00%
Utua	3.81%	0.00%	0.00%	0.00%	0.00%	0.00%
Vega Alta	0.87%	0.97%	0.00%	0.00%	0.00%	0.00%
Vega Baja	1.06%	5.20%	4.94%	0.46%	0.00%	0.00%
Vieques	0.76%	4.41%	12.14%	8.55%	0.73%	0.00%
Villalba	1.23%	0.00%	0.00%	0.00%	0.00%	0.00%
Yabucoa	1.58%	2.32%	2.64%	1.02%	0.00%	0.00%
Yauco	2.25%	0.00%	0.53%	0.00%	0.00%	0.00%

Table 39: Category 5 Storm Surge Hazard Scores and Ranks by Municipio

Municipio	Hurricane Category 5 Storm Surge Hazard Score (Log Multiplied)		
	Total Score	Standardized Score (0-1)	Rank of Score (1-78)
Lajas	10438.0640	1.0000	1
Salinas	9569.7114	0.9168	2
Carolina	8885.3158	0.8512	3
Humacao	8709.2810	0.8344	4
Loiza	7753.2376	0.7428	5
Canovanas	5772.8938	0.5531	6
Ponce	5044.5718	0.4833	7
Ceiba	4632.9955	0.4439	8
Naguabo	4468.3742	0.4281	9
Santa Isabel	3310.1225	0.3171	10
Guayama	2877.0056	0.2756	11
Fajardo	2814.5156	0.2696	12
Cabo Rojo	2008.4657	0.1924	13
Juana Diaz	1896.7247	0.1817	14

Mayaguez	1316.7920	0.1262	15
Guayanilla	907.4509	0.0869	16
Rio Grande	523.3309	0.0501	17
Guanica	411.3057	0.0394	18
Penuelas	322.8076	0.0309	19
Catano	187.5036	0.018	20
Vieques	128.6291	0.0123	21
Aguadilla	114.3571	0.011	22
Bayamon	113.6448	0.0109	23
San Juan	81.9124	0.0078	24
Aguada	36.7976	0.0035	25
Luquillo	13.8820	0.0013	26
Yabucoa	11.0548	0.0011	27
Arecibo	9.2919	0.0009	28
Culebra	8.6345	0.0008	29
Vega Baja	8.4675	0.0008	29
Toa Baja	7.6673	0.0007	31
Dorado	4.7245	0.0005	32
Patillas	3.7351	0.0004	33
Guaynabo	3.5516	0.0003	34
Rincon	1.8156	0.0002	35
Anasco	0.9875	0.0001	36
Arroyo	0.9330	0.0001	36
Barceloneta	0.8107	0.0001	36
Camuy	0.8672	0.0001	36
Hatillo	1.1256	0.0001	36
Isabela	1.0409	0.0001	36
Manati	1.2963	0.0001	36
Maunabo	0.6432	0.0001	36
Quebradillas	0.6010	0.0001	36
Adjuntas	0.0000	0.0000	45
Aguas Buenas	0.0000	0.0000	45
Aibonito	0.0000	0.0000	45
Barranquitas	0.0000	0.0000	45
Caguas	0.0000	0.0000	45
Cayey	0.0000	0.0000	45
Ciales	0.0000	0.0000	45
Cidra	0.0000	0.0000	45
Coamo	0.0000	0.0000	45
Comerio	0.0000	0.0000	45
Corozal	0.0000	0.0000	45
Florida	0.0000	0.0000	45

Gurabo	0.0000	0.0000	45
Hormigueros	0.0000	0.0000	45
Jayuya	0.0000	0.0000	45
Juncos	0.0000	0.0000	45
Lares	0.0000	0.0000	45
Las Marias	0.0000	0.0000	45
Las Piedras	0.0000	0.0000	45
Maricao	0.0000	0.0000	45
Moca	0.0000	0.0000	45
Morovis	0.0000	0.0000	45
Naranjito	0.0000	0.0000	45
Orocovis	0.0000	0.0000	45
Sabana Grande	0.0000	0.0000	45
San German	0.0000	0.0000	45
San Lorenzo	0.0000	0.0000	45
San Sebastian	0.0000	0.0000	45
Toa Alta	0.0000	0.0000	45
Trujillo Alto	0.0000	0.0000	45
Utado	0.0000	0.0000	45
Vega Alta	0.0897	0.0000	45
Villalba	0.0000	0.0000	45
Yauco	0.4349	0.0000	45

Earthquakes

Hazard Overview

As most of the Caribbean, Puerto Rico is subject to significant threat from earthquakes. Earthquakes represent a particularly severe threat due to irregular time intervals between these events, lack of adequate forecasts and the catastrophic damage that can occur as a result of a significant event of this nature.

An earthquake is caused by the release of stored energy within or along the edge of the tectonic plates of the Earth. They are characterized by a sudden shaking of the earth. The severity of an earthquake depends on its place of origin (epicenter) and the amount of energy released. Upon the occurrence of the earthquake, seismic waves radiate from the earthquake source, causing the shaking of the earth. The severity of the tremor increases as energy is released, and decreases according to its distance from the epicenter. The tremors can be felt hundreds of miles from its epicenter. The intensity of shaking is the result of several factors, such as: the extent and type of earthquake, the distance from this, the area's soil conditions, and the relative orientation of the site with respect to the seismic event.

Among the damages earthquakes can cause are liquefaction, landslides, and significant damage to buildings and infrastructure. Liquefaction is a phenomenon that causes unconsolidated soils to lose their strength and act like a viscous fluid (like quicksand) when these soils are subject to tremors due to an earthquake. The frequency and intensity of liquefaction that can occur during an earthquake is due to several factors including: the geological conditions of the area, groundwater depth, the tremor severity, and magnitude of the earthquake.

Earthquakes can cause landslides and other types of soil failures. Landslides are sudden movements of materials that emerge from the hills or mountains, free fall, sliding or rolling down. Landslides caused by earthquakes can occur on natural slopes, cut slopes on the ground, eroded rocks, or filled slopes. They are common in areas where they are abruptly cut off the slopes, on plain soils or fractured eroded rock. The frequency and intensity of landslides that may occur during an earthquake is due to several factors, including: geological materials contained in the area, the steepness of the slope, the water content of the material that slides, trembling land and the magnitude of the earthquake.

Data and Methods

The United States Geological Survey (USGS), charged with overseeing all geophysical hazard activity in the United State and its protectorates, has completed several studies of earthquake risk for Puerto Rico. Among the most recent is a 2003 study of U.S. Seismic Hazard Maps – Puerto Rico and the U.S.

Virgin Islands, Samoa and the Pacific Islands, and Guam and Northern Mariana Islands.²⁰ This study provides gridded seismic hazard curve data, gridded ground motion data, and mapped gridded ground motion values for the Puerto Rico region. In this case, as in many probabilistic seismic hazard analysis (PSHA), the greater than 2% probability of peak ground acceleration (PGA) has become the defacto measure for estimating seismic activity.²¹ Although considerable discussion in seismology, engineering, and emergency management is beginning to shift away from PSHA and PGA as a measure of risk^{22, 23} (eg. hazard X vulnerability) it still proves to be useful for understanding the occurrence frequency of ground shaking. For the purposes of this hazard assessment, the > 2% exceedance of Peak Ground Acceleration provides a useful tool for understanding where the hazard is likely to occur, but not which buildings or communities are likely to be adversely impacted. In this assessment, average PGA values were calculated for each hexagonal grid and mapped using standard deviations showing us a clear pattern of increased hazard across the island.

Hazard Frequency Analysis Results

Figure 15 shows that earthquake threat generally decreases from southwest to northeast across Puerto Rico. Four municipios, Cabo Rojo, Lajas, Guanica, and Yauco have greater than 10 sq. miles of land area in the highest PGA zones, and 36 municipios have greater than 10 sq. miles in the second highest hazard category (Table 40). Thirty-three municipios have 100% of their land area in a high or medium high earthquake hazard zone as defined by PGA of 40 or greater (Table 41). Table 42 provides a breakdown of municipio/hazard threat category as a ratio of total island area, highlighting the highest hazard threat across the island in a numerically comparable way. Finally, Table 43, summarizes across all earthquake hazard zones and ranks each municipio based on earthquake hazard threat.

²⁰ https://www.usgs.gov/natural-hazards/earthquake-hazards/science/us-seismic-hazard-maps-puerto-rico-and-us-virgin-islands?qt-science_center_objects=0#qt-science_center_objects

²¹ http://www.opensha.org/sites/opensha.org/files/PSHA_Primer_v2_0.pdf

²² https://www.iitk.ac.in/nicee/wcee/article/14_S27-001.PDF

²³ <https://www.sciencedirect.com/science/article/pii/S0031920116303016>

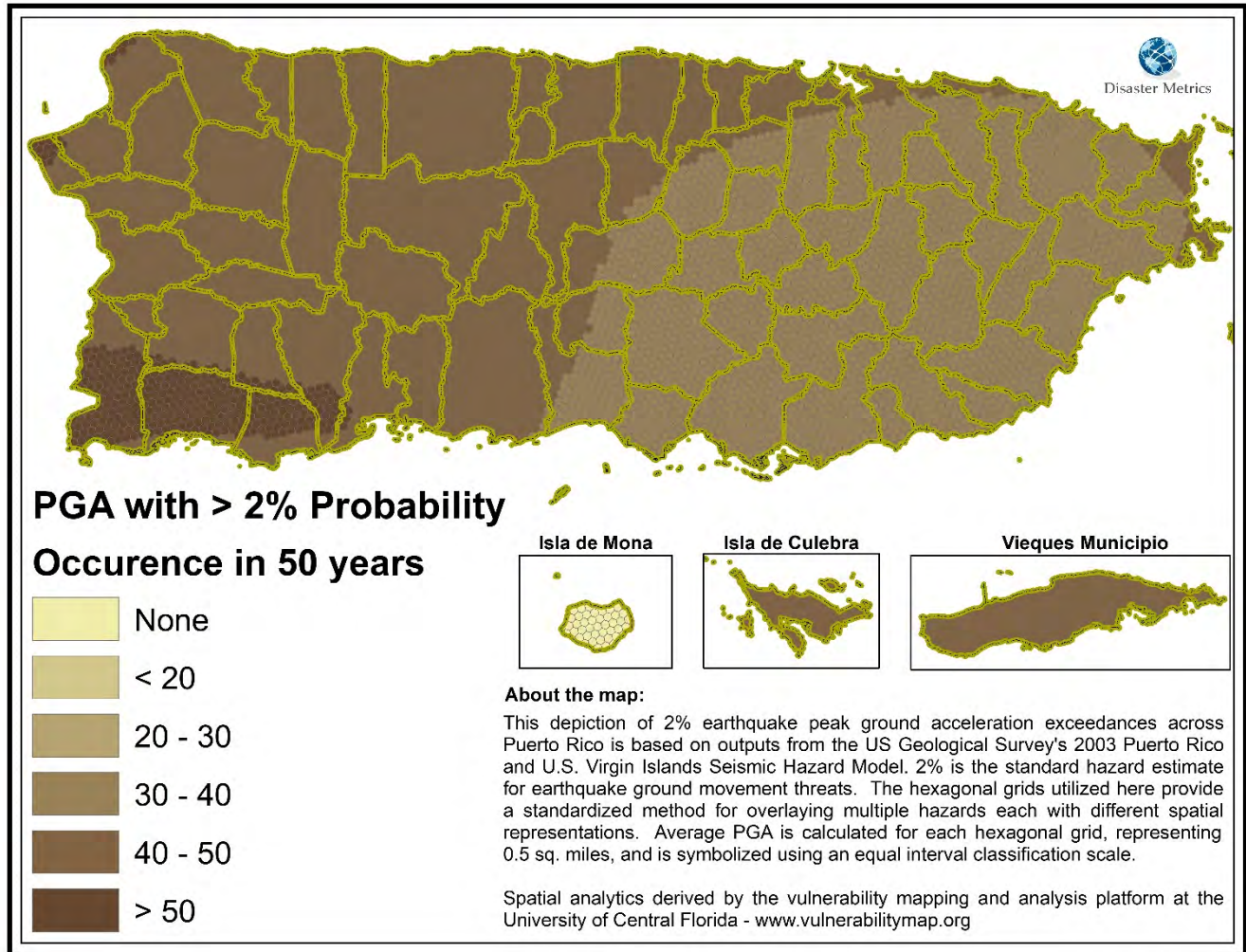


Figure 15: Earthquake Hazard Areas

Table 40: Earthquake Hazard by Municipio and Areal Extent

Municipio	HEX GRID Area by >2% Probability of Earthquake Peak Ground Acceleration (Sq. miles)					
	None	Low (PGA < 20)	Medium Low (PGA 20 - 30)	Medium (PGA 30 - 40)	Medium High (PGA 40 - 50)	High (> PGA > 50)
Adjuntas					67.10	
Aguada					29.84	1.09
Aguadilla					32.54	4.06
Aguas Buenas				30.10		
Aibonito				31.34		
Anasco					39.56	
Arecibo					126.97	
Arroyo				15.05		
Barceloneta					18.76	
Barranquitas				34.28		
Bayamon				38.87	5.64	
Cabo Rojo					20.41	52.70

Caguas				59.07		
Camuy					46.37	
Canovanas				33.01		
Carolina				42.29	5.02	
Catano					5.08	
Cayey				51.96		
Ceiba				20.67	9.70	
Ciales					66.71	
Cidra				36.46		
Coamo				78.03		
Comerio				28.52		
Corozal				37.65	4.93	
Culebra					13.31	
Dorado					23.42	
Fajardo				16.45	14.06	
Florida					15.22	
Guanica					15.50	23.51
Guayama				65.87		
Guayanilla					40.64	2.35
Guaynabo				25.53	2.24	
Gurabo				28.31		
Hatillo					41.84	
Hormigueros					11.34	
Humacao				45.10		
Isabela					55.41	
Jayuya					44.53	
Juana Diaz				41.29	19.44	
Juncos				26.62		
Lajas	0.00				3.75	57.61
Lares					61.64	
Las Marias					46.51	
Las Piedras				33.89		
Loiza				12.02	8.52	
Luquillo				23.66	2.20	
Manati					46.82	
Maricao					36.63	
Maunabo				21.09		
Mayaguez	22.18				55.20	0.59
Moca					50.37	
Morovis				6.94	31.98	
Naguabo				51.88		
Naranjito				27.75		

Orocovis				42.84	20.93	
Patillas				47.21	0.00	
Penuelas					44.76	
Ponce				2.88	114.10	
Quebradillas					23.14	
Rincon					8.82	5.57
Rio Grande				60.77	0.04	
Sabana Grande					28.90	6.94
Salinas				70.06		
San German					48.68	5.82
San Juan	0.00			39.00	10.53	
San Lorenzo				53.21		
San Sebastian					71.22	
Santa Isabel				34.57		
Toa Alta				19.05	8.51	
Toa Baja				0.29	23.51	
Trujillo Alto				21.38		
Utuado					115.07	
Vega Alta				0.07	27.67	
Vega Baja					46.65	
Vieques	0.00				53.18	
Villalba				21.98	15.05	
Yabucoa				55.28	0.12	
Yauco					56.34	12.48
Grand Total	22.19	149.32	128.66	1432.29	1836.43	172.73

Table 41: Percent of (Municipio) Hexagonal Area by Earthquake Hazard per Municipio

Municipio	HEX GRID Area by >2% Probability of Earthquake Peak Ground Acceleration (Sq. miles)					
	None	Low (PGA < 20)	Medium Low (PGA 20 - 30)	Medium (PGA 30 - 40)	Medium High (PGA 40 - 50)	High (> PGA > 50)
Adjuntas	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%
Aguada	0.00%	0.00%	0.00%	0.00%	96.48%	3.52%
Aguadilla	0.00%	0.00%	0.00%	0.00%	88.91%	11.09%
Aguas Buenas	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Aibonito	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Anasco	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%
Arecibo	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%
Arroyo	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Barceloneta	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%
Barranquitas	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Bayamon	0.00%	0.00%	0.00%	87.33%	12.67%	0.00%
Cabo Rojo	0.00%	0.00%	0.00%	0.00%	27.92%	72.08%

Caguas	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Camuy	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%
Canovanas	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Carolina	0.00%	0.00%	0.00%	89.39%	10.61%	0.00%
Catano	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%
Cayey	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Ceiba	0.00%	0.00%	0.00%	68.06%	31.94%	0.00%
Ciales	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%
Cidra	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Coamo	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Comerio	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Corozal	0.00%	0.00%	0.00%	88.42%	11.58%	0.00%
Culebra	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%
Dorado	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%
Fajardo	0.00%	0.00%	0.00%	53.91%	46.09%	0.00%
Florida	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%
Guanica	0.00%	0.00%	0.00%	0.00%	39.74%	60.26%
Guayama	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Guayanilla	0.00%	0.00%	0.00%	0.00%	94.52%	5.48%
Guaynabo	0.00%	0.00%	0.00%	91.95%	8.05%	0.00%
Gurabo	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Hatillo	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%
Hormigueros	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%
Humacao	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Isabela	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%
Jayuya	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%
Juana Diaz	0.00%	0.00%	0.00%	67.98%	32.02%	0.00%
Juncos	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Lajas	0.00%	0.00%	0.00%	0.00%	6.11%	93.89%
Lares	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%
Las Marias	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%
Las Piedras	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Loiza	0.00%	0.00%	0.00%	58.53%	41.47%	0.00%
Luquillo	0.00%	0.00%	0.00%	91.51%	8.49%	0.00%
Manati	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%
Maricao	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%
Maunabo	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Mayaguez	28.45%	0.00%	0.00%	0.00%	70.80%	0.75%
Moca	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%
Morovis	0.00%	0.00%	0.00%	17.83%	82.17%	0.00%
Naguabo	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Naranjito	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%

Orocovis	0.00%	0.00%	0.00%	67.18%	32.82%	0.00%
Patillas	0.00%	0.00%	0.00%	99.99%	0.01%	0.00%
Penuelas	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%
Ponce	0.00%	0.00%	0.00%	2.46%	97.54%	0.00%
Quebradillas	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%
Rincon	0.00%	0.00%	0.00%	0.00%	61.33%	38.67%
Rio Grande	0.00%	0.00%	0.00%	99.93%	0.07%	0.00%
Sabana Grande	0.00%	0.00%	0.00%	0.00%	80.64%	19.36%
Salinas	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%
San German	0.00%	0.00%	0.00%	0.00%	89.31%	10.69%
San Juan	0.00%	0.00%	0.00%	78.74%	21.26%	0.00%
San Lorenzo	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%
San Sebastian	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%
Santa Isabel	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Toa Alta	0.00%	0.00%	0.00%	69.12%	30.88%	0.00%
Toa Baja	0.00%	0.00%	0.00%	1.22%	98.78%	0.00%
Trujillo Alto	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Utuado	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%
Vega Alta	0.00%	0.00%	0.00%	0.26%	99.74%	0.00%
Vega Baja	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%
Vieques	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%
Villalba	0.00%	0.00%	0.00%	59.36%	40.64%	0.00%
Yabucoa	0.00%	0.00%	0.00%	99.78%	0.22%	0.00%
Yauco	0.00%	0.00%	0.00%	0.00%	81.87%	18.13%
Grand Total	22.19	149.32	128.66	1432.29	1836.43	172.73

Table 42: Percent of (Island) Hexagonal Area by Earthquake Hazard per Municipio

Municipio	>2% Probability of Earthquake Peak Ground Acceleration Percent Area by Total (Island) Land Area					
	None	Low (PGA < 20)	Medium Low (PGA 20 - 30)	Medium (PGA 30 - 40)	Medium High (PGA 40 - 50)	High (> PGA > 50)
Adjuntas	0.00%	0.00%	0.00%	0.00%	3.65%	0.00%
Aguada	0.00%	0.00%	0.00%	0.00%	1.62%	0.63%
Aguadilla	0.00%	0.00%	0.00%	0.00%	1.77%	2.35%
Aguas Buenas	0.00%	0.00%	0.00%	2.10%	0.00%	0.00%
Aibonito	0.00%	0.00%	0.00%	2.19%	0.00%	0.00%
Anasco	0.00%	0.00%	0.00%	0.00%	2.15%	0.00%
Arecibo	0.00%	0.00%	0.00%	0.00%	6.91%	0.00%
Arroyo	0.00%	0.00%	0.00%	1.05%	0.00%	0.00%
Barceloneta	0.00%	0.00%	0.00%	0.00%	1.02%	0.00%
Barranquitas	0.00%	0.00%	0.00%	2.39%	0.00%	0.00%
Bayamon	0.00%	0.00%	0.00%	2.71%	0.31%	0.00%

Cabo Rojo	0.00%	0.00%	0.00%	0.00%	1.11%	30.51%
Caguas	0.00%	0.00%	0.00%	4.12%	0.00%	0.00%
Camuy	0.00%	0.00%	0.00%	0.00%	2.53%	0.00%
Canovanas	0.00%	0.00%	0.00%	2.30%	0.00%	0.00%
Carolina	0.00%	0.00%	0.00%	2.95%	0.27%	0.00%
Catano	0.00%	0.00%	0.00%	0.00%	0.28%	0.00%
Cayey	0.00%	0.00%	0.00%	3.63%	0.00%	0.00%
Ceiba	0.00%	0.00%	0.00%	1.44%	0.53%	0.00%
Ciales	0.00%	0.00%	0.00%	0.00%	3.63%	0.00%
Cidra	0.00%	0.00%	0.00%	2.55%	0.00%	0.00%
Coamo	0.00%	0.00%	0.00%	5.45%	0.00%	0.00%
Comerio	0.00%	0.00%	0.00%	1.99%	0.00%	0.00%
Corozal	0.00%	0.00%	0.00%	2.63%	0.27%	0.00%
Culebra	0.00%	0.00%	0.00%	0.00%	0.72%	0.00%
Dorado	0.00%	0.00%	0.00%	0.00%	1.28%	0.00%
Fajardo	0.00%	0.00%	0.00%	1.15%	0.77%	0.00%
Florida	0.00%	0.00%	0.00%	0.00%	0.83%	0.00%
Guanica	0.00%	0.00%	0.00%	0.00%	0.84%	13.61%
Guayama	0.00%	0.00%	0.00%	4.60%	0.00%	0.00%
Guayanilla	0.00%	0.00%	0.00%	0.00%	2.21%	1.36%
Guaynabo	0.00%	0.00%	0.00%	1.78%	0.12%	0.00%
Gurabo	0.00%	0.00%	0.00%	1.98%	0.00%	0.00%
Hatillo	0.00%	0.00%	0.00%	0.00%	2.28%	0.00%
Hormigueros	0.00%	0.00%	0.00%	0.00%	0.62%	0.00%
Humacao	0.00%	0.00%	0.00%	3.15%	0.00%	0.00%
Isabela	0.00%	0.00%	0.00%	0.00%	3.02%	0.00%
Jayuya	0.00%	0.00%	0.00%	0.00%	2.43%	0.00%
Juana Diaz	0.00%	0.00%	0.00%	2.88%	1.06%	0.00%
Juncos	0.00%	0.00%	0.00%	1.86%	0.00%	0.00%
Lajas	0.01%	0.00%	0.00%	0.00%	0.20%	33.36%
Lares	0.00%	0.00%	0.00%	0.00%	3.36%	0.00%
Las Marias	0.00%	0.00%	0.00%	0.00%	2.53%	0.00%
Las Piedras	0.00%	0.00%	0.00%	2.37%	0.00%	0.00%
Loiza	0.00%	0.00%	0.00%	0.84%	0.46%	0.00%
Luquillo	0.00%	0.00%	0.00%	1.65%	0.12%	0.00%
Manati	0.00%	0.00%	0.00%	0.00%	2.55%	0.00%
Maricao	0.00%	0.00%	0.00%	0.00%	1.99%	0.00%
Maunabo	0.00%	0.00%	0.00%	1.47%	0.00%	0.00%
Mayaguez	99.98%	0.00%	0.00%	0.00%	3.01%	0.34%
Moca	0.00%	0.00%	0.00%	0.00%	2.74%	0.00%
Morovis	0.00%	0.00%	0.00%	0.48%	1.74%	0.00%
Naguabo	0.00%	0.00%	0.00%	3.62%	0.00%	0.00%

Naranjito	0.00%	0.00%	0.00%	1.94%	0.00%	0.00%
Orocovis	0.00%	0.00%	0.00%	2.99%	1.14%	0.00%
Patillas	0.00%	0.00%	0.00%	3.30%	0.00%	0.00%
Penuelas	0.00%	0.00%	0.00%	0.00%	2.44%	0.00%
Ponce	0.00%	0.00%	0.00%	0.20%	6.21%	0.00%
Quebradillas	0.00%	0.00%	0.00%	0.00%	1.26%	0.00%
Rincon	0.00%	0.00%	0.00%	0.00%	0.48%	3.22%
Rio Grande	0.00%	0.00%	0.00%	4.24%	0.00%	0.00%
Sabana Grande	0.00%	0.00%	0.00%	0.00%	1.57%	4.02%
Salinas	0.00%	0.00%	0.00%	4.89%	0.00%	0.00%
San German	0.00%	0.00%	0.00%	0.00%	2.65%	3.37%
San Juan	0.01%	0.00%	0.00%	2.72%	0.57%	0.00%
San Lorenzo	0.00%	0.00%	0.00%	3.71%	0.00%	0.00%
San Sebastian	0.00%	0.00%	0.00%	0.00%	3.88%	0.00%
Santa Isabel	0.00%	0.00%	0.00%	2.41%	0.00%	0.00%
Toa Alta	0.00%	0.00%	0.00%	1.33%	0.46%	0.00%
Toa Baja	0.00%	0.00%	0.00%	0.02%	1.28%	0.00%
Trujillo Alto	0.00%	0.00%	0.00%	1.49%	0.00%	0.00%
Utua	0.00%	0.00%	0.00%	0.00%	6.27%	0.00%
Vega Alta	0.00%	0.00%	0.00%	0.00%	1.51%	0.00%
Vega Baja	0.00%	0.00%	0.00%	0.00%	2.54%	0.00%
Vieques	0.01%	0.00%	0.00%	0.00%	2.90%	0.00%
Villalba	0.00%	0.00%	0.00%	1.53%	0.82%	0.00%
Yabucoa	0.00%	0.00%	0.00%	3.86%	0.01%	0.00%
Yauco	0.00%	0.00%	0.00%	0.00%	3.07%	7.23%

Table 43: Earthquake Hazard Scores and Ranks by Municipio

Municipio	Earthquake Hazard Score (Log Multiplied)		
	Total Score	Standardized Score (0-1)	Rank of Score (1-78)
Lajas	10029.5216	1	1
Cabo Rojo	9308.5181	0.928	2
Guanica	4202.6147	0.4179	3
Yauco	2609.7743	0.2588	4
Sabana Grande	1431.8902	0.1411	5
San German	1394.4018	0.1374	6
Rincon	1035.4309	0.1015	7
Arecibo	1000.0000	0.098	8
Aguadilla	961.2002	0.0941	9
Utua	906.2384	0.0886	10
Ponce	902.2966	0.0882	11

Guayanilla	728.5981	0.0709	12
San Sebastian	560.8899	0.0541	13
Mayaguez	536.9325	0.0517	14
Adjuntas	528.4201	0.0509	15
Ciales	525.3555	0.0506	16
Lares	485.4330	0.0466	17
Isabela	436.3739	0.0417	18
Aguada	423.8025	0.0404	19
Vieques	418.8334	0.0399	20
Moca	396.6589	0.0377	21
Manati	368.7413	0.0349	22
Vega Baja	367.3796	0.0348	23
Las Marias	366.2568	0.0347	24
Camuy	365.2022	0.0346	25
Penuelas	352.4840	0.0333	26
Jayuya	350.7355	0.0331	27
Hatillo	329.5046	0.031	28
Anasco	311.5538	0.0292	29
Maricao	288.4623	0.0269	30
Morovis	260.7905	0.0241	31
Orocovis	219.7516	0.02	32
Vega Alta	218.0046	0.0199	33
Juana Diaz	206.0491	0.0187	34
Toa Baja	185.5580	0.0166	35
Dorado	184.4249	0.0165	36
Quebradillas	182.2401	0.0163	37
Barceloneta	147.7382	0.0128	38
Villalba	146.7126	0.0127	39
San Juan	132.9075	0.0114	40
Fajardo	131.8226	0.0112	41
Florida	119.8846	0.01	42
Culebra	104.8017	0.0085	43
Ceiba	102.8938	0.0084	44
Coamo	100.0000	0.0081	45
Bayamon	94.2540	0.0075	46
Carolina	93.7068	0.0074	47
Toa Alta	91.4398	0.0072	48
Hormigueros	89.3423	0.007	49
Salinas	89.7869	0.007	49
Corozal	87.0774	0.0068	51
Guayama	84.4157	0.0065	52
Loiza	82.4649	0.0063	53

Rio Grande	78.2051	0.0059	54
Caguas	75.7008	0.0056	55
Yabucoa	71.8283	0.0052	56
San Lorenzo	68.1895	0.0049	57
Cayey	66.5934	0.0047	58
Naguabo	66.4907	0.0047	58
Patillas	60.5348	0.0041	60
Humacao	57.8050	0.0038	61
Guaynabo	50.3297	0.0031	62
Luquillo	47.6235	0.0028	63
Cidra	46.7209	0.0027	64
Barranquitas	43.9367	0.0025	65
Santa Isabel	44.3102	0.0025	65
Las Piedras	43.4364	0.0024	67
Canovanas	42.3003	0.0023	68
Aibonito	40.1634	0.0021	69
Catano	40.0417	0.0021	69
Aguas Buenas	38.5708	0.0019	71
Comerio	36.5564	0.0017	72
Gurabo	36.2859	0.0017	72
Naranjito	35.5621	0.0016	74
Juncos	34.1101	0.0015	75
Maunabo	27.0275	0.0008	76
Trujillo Alto	27.4030	0.0008	76
Arroyo	19.2846	0.0000	78

Tsunami

Hazard Overview

A tsunami is a series of waves caused generally by a vertical displacement on the bottom (bed) of the sea caused by an earthquake under the seabed. Tsunamis can also be caused by underwater landslides or volcanic eruptions. Tsunami characteristics are different in deep and surface water events. In deep water, waves travel at speeds up to 500 mph but the visual indication of deep water tsunami's is typically a low wave under one foot in height. However, as these deep water waves approach coastal areas they greatly decrease in speed and dramatically increase in height. Near shore tsunami waves, sometimes reaching heights of more than 30 meters (98 feet), can cause great impacts to lives, property and livelihoods when they impact the coast.²⁴

Data and Methods

Puerto Rico's Seismic Network (PRSN), part of the Department of Geology of the University of Puerto Rico in Mayagüez, has a mission to detect, process and investigate the seismic activity in the region of Puerto Rico to aid in public security, education, engineering and scientific research. In 2012, PRSN completed a tsunami inundation model considering an 8.5 magnitude catastrophic event on the north of Puerto Rico.²⁵ Results of this model include geospatial data files displaying flood inundation areas across Puerto Rico. Like flood hazard, these polygonal representations of tsunami hazard were spatially intersected with Puerto Rico's 0.5-mile hexagonal grid to produce a spatial representation of tsunami inundation hazard across the island.

Hazard Frequency Analysis Results

Tsunamis are mainly a coastal hazard yet potential impacts are uneven across the coastline (Figure 16). Municipios on the north shore of Puerto Rico appear to have more land area in tsunami hazard zones in comparison to other parts of the island. These results are dependent on many factors, but could be related to the fact that the 2012 model was based on an event in the north of Puerto Rico. Additionally, municipios along Puerto Rico's western shore have land areas in high tsunami hazard zones. Thirty-seven municipios have land in high tsunami impact areas (Table 44) with Loiza topping the list in terms of total land area in high tsunami hazard zone (Figure 16). Table 47 provides a standardized score and rank for each municipio in terms of its tsunami hazard threat.

²⁴ <https://recovery.pr/en/document-library>

²⁵ <http://redsismica.uprm.edu/English/tsunami/tsunamiiprogram/prc/gisdataenglish.php>

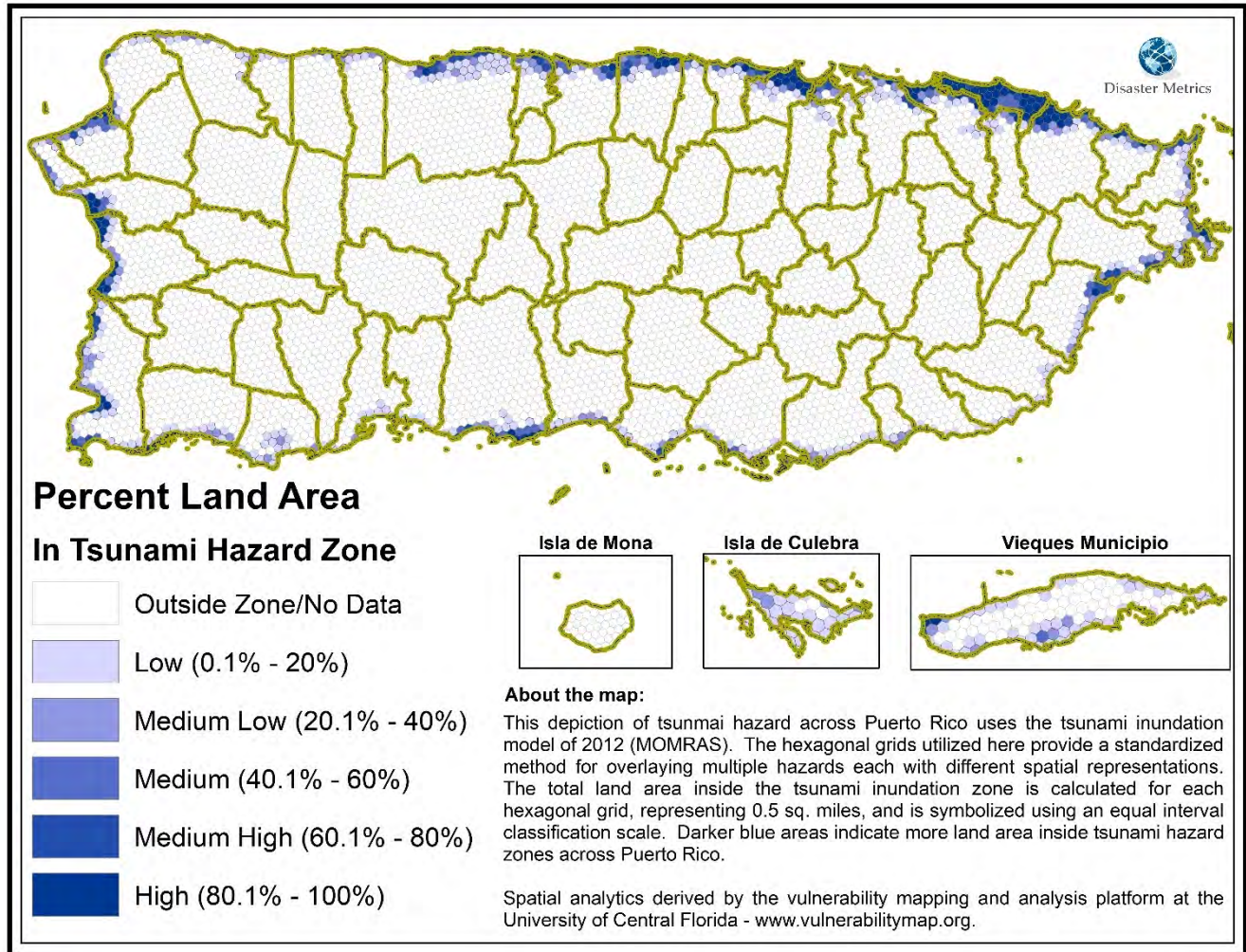


Figure 16: Tsunami Hazard Areas

Table 44: Tsunami Hazard by Municipio and Areal Extent

Municipio	HEX GRID Area by Tsunami Inundation (Sq. miles)					
	None	Low (0.1% – 20%)	Medium Low (20.1% - 40%)	Medium (40.1% - 60%)	Medium High (60.1% - 80%)	High (>80%)
Adjuntas	67.10					
Aguada	22.44	2.20	1.80	1.50	1.40	1.59
Aguadilla	29.82	4.23	0.94	0.59	0.43	0.59
Aguas Buenas	30.10					
Aibonito	31.34					
Anasco	32.13	3.33	0.54	1.00		2.57
Arecibo	105.93	13.09	1.59	1.83	3.28	1.25
Arroyo	12.03	1.40	1.21	0.29		0.11
Barceloneta	11.52	2.97	1.69	0.79	1.36	0.43
Barranquitas	34.28					
Bayamon	41.13	2.71	0.45			0.23
Cabo Rojo	47.64	11.57	4.95	2.78	3.75	2.43

Caguas	59.07						
Camuy	43.99	1.35	0.43		0.51	0.08	
Canovanas	28.16	2.80	1.13	0.03	0.52	0.37	
Carolina	33.86	5.71	0.95	1.64	0.94	4.20	
Catano	0.99	0.25	1.53	0.49	0.72	1.10	
Cayey	51.96						
Ceiba	17.93	6.30	1.54	1.93	1.16	1.52	
Ciales	66.71						
Cidra	36.46						
Coamo	78.03						
Comerio	28.52						
Corozal	42.58						
Culebra	1.69	10.05	1.56				
Dorado	16.04	2.60	0.46	1.38	0.51	2.42	
Fajardo	19.95	5.77	1.41	0.89	1.83	0.67	
Florida	15.22						
Guanica	28.76	8.31	1.82	0.01	0.11		
Guayama	56.51	6.03	1.66	0.33	1.00	0.33	
Guayanilla	37.06	5.37	0.56				
Guaynabo	26.37	1.01	0.39				
Gurabo	28.31						
Hatillo	36.97	2.38	1.47	0.26	0.61	0.15	
Hormigueros	11.14	0.21					
Humacao	34.61	4.15	2.08	2.30	1.20	0.76	
Isabela	47.55	4.81	2.07	0.50		0.47	
Jayuya	44.53						
Juana Diaz	55.52	2.56	1.27	0.61	0.39	0.39	
Juncos	26.62						
Lajas	52.28	6.20	2.01		0.53	0.34	
Lares	61.64						
Las Marias	46.51						
Las Piedras	33.89						
Loiza	0.62	0.70	0.37	2.66	1.95	14.24	
Luquillo	19.06	2.54	1.89	0.69	0.53	1.15	
Manati	38.10	2.84	2.21	1.14	1.60	0.94	
Maricao	36.63						
Maunabo	18.64	2.45					
Mayaguez	65.89	3.76	1.97	0.88	0.26	5.21	
Moca	50.37						
Morovis	38.93						
Naguabo	43.10	3.46	2.41	0.41	2.25	0.24	
Naranjito	27.75						

Orocovis	63.78						
Patillas	43.53	3.11	0.37	0.21			
Penuelas	41.47	2.59	0.02	0.47	0.08	0.13	
Ponce	104.44	4.63	1.60	2.68	1.24	2.39	
Quebradillas	20.02	2.96	0.16				
Rincon	8.77	2.64	1.52	0.93	0.31	0.22	
Rio Grande	47.74	2.50	2.06	0.76	1.81	5.95	
Sabana Grande	35.84						
Salinas	61.65	5.14	0.60	0.58	1.14	0.96	
San German	54.51						
San Juan	38.16	6.80	1.65	0.39	1.45	1.07	
San Lorenzo	53.21						
San Sebastian	71.22						
Santa Isabel	27.45	4.46	0.65	0.69	1.02	0.30	
Toa Alta	27.56						
Toa Baja	11.35	4.02	1.71	0.01	0.54	6.17	
Trujillo Alto	21.38						
Utuado	115.07						
Vega Alta	25.22	1.07	0.63		0.62	0.19	
Vega Baja	34.55	2.57	2.47	1.86	2.43	2.78	
Vieques	29.53	19.53	2.53	0.70	0.18	0.71	
Villalba	37.04						
Yabucoa	51.14	4.16		0.01	0.10		
Yauco	68.14	0.68					
Grand Total	3066.71	199.97	60.31	34.23	37.77	64.64	

Table 45: Percent of (Municipio) Hexagonal Area by Tsunami Hazard per Municipio

Municipio	Tsunami Inundation Percent Area by Total (Municipio) Land Area					
	None	Low (0.1% – 20%)	Medium Low (20.1% - 40%)	Medium (40.1% - 60%)	Medium High (60.1% - 80%)	High (>80%)
Adjuntas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Aguada	72.57%	7.11%	5.82%	4.85%	4.52%	5.13%
Aguadilla	81.46%	11.57%	2.58%	1.61%	1.18%	1.60%
Aguas Buenas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Aibonito	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Anasco	81.21%	8.41%	1.36%	2.53%	0.00%	6.49%
Arecibo	83.43%	10.31%	1.26%	1.44%	2.58%	0.98%
Arroyo	79.97%	9.31%	8.06%	1.94%	0.00%	0.72%
Barceloneta	61.39%	15.85%	9.01%	4.20%	7.27%	2.28%
Barranquitas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Bayamon	92.39%	6.09%	1.01%	0.00%	0.00%	0.51%
Cabo Rojo	65.16%	15.82%	6.77%	3.80%	5.13%	3.33%

Caguas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Camuy	94.87%	2.92%	0.93%	0.00%	1.11%	0.17%
Canovanas	85.32%	8.48%	3.42%	0.10%	1.57%	1.12%
Carolina	71.58%	12.07%	2.01%	3.47%	1.98%	8.89%
Catano	19.48%	4.97%	30.04%	9.57%	14.23%	21.71%
Cayey	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Ceiba	59.03%	20.73%	5.08%	6.34%	3.83%	4.99%
Ciales	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Cidra	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Coamo	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Comerio	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Corozal	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Culebra	12.73%	75.54%	11.72%	0.00%	0.00%	0.00%
Dorado	68.51%	11.10%	1.98%	5.88%	2.19%	10.35%
Fajardo	65.37%	18.92%	4.61%	2.91%	5.98%	2.20%
Florida	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Guanica	73.73%	21.30%	4.67%	0.01%	0.29%	0.00%
Guayama	85.80%	9.15%	2.52%	0.50%	1.52%	0.51%
Guayanilla	86.21%	12.49%	1.30%	0.00%	0.00%	0.00%
Guaynabo	94.96%	3.65%	1.39%	0.00%	0.00%	0.00%
Gurabo	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Hatillo	88.37%	5.68%	3.51%	0.62%	1.45%	0.36%
Hormigueros	98.18%	1.82%	0.00%	0.00%	0.00%	0.00%
Humacao	76.73%	9.21%	4.61%	5.11%	2.66%	1.68%
Isabela	85.82%	8.68%	3.73%	0.91%	0.00%	0.85%
Jayuya	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Juana Diaz	91.42%	4.21%	2.09%	1.01%	0.64%	0.64%
Juncos	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lajas	85.20%	10.11%	3.27%	0.00%	0.87%	0.56%
Lares	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Marias	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Piedras	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Loiza	3.01%	3.39%	1.81%	12.96%	9.48%	69.34%
Luquillo	73.70%	9.82%	7.29%	2.67%	2.06%	4.46%
Manati	81.37%	6.06%	4.73%	2.43%	3.41%	2.01%
Maricao	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Maunabo	88.38%	11.62%	0.00%	0.00%	0.00%	0.00%
Mayaguez	84.51%	4.82%	2.52%	1.13%	0.34%	6.68%
Moca	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Morovis	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Naguabo	83.08%	6.67%	4.65%	0.79%	4.35%	0.47%
Naranjito	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Orocovis	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Patillas	92.19%	6.58%	0.78%	0.45%	0.00%	0.00%
Penuelas	92.66%	5.78%	0.03%	1.04%	0.19%	0.29%
Ponce	89.28%	3.96%	1.37%	2.29%	1.06%	2.04%
Quebradillas	86.53%	12.79%	0.68%	0.00%	0.00%	0.00%
Rincon	60.96%	18.34%	10.56%	6.46%	2.15%	1.54%
Rio Grande	78.50%	4.11%	3.38%	1.25%	2.97%	9.78%
Sabana Grande	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Salinas	87.99%	7.33%	0.85%	0.83%	1.62%	1.37%
San German	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
San Juan	77.06%	13.73%	3.34%	0.79%	2.93%	2.15%
San Lorenzo	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
San Sebastian	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Santa Isabel	79.40%	12.90%	1.89%	1.99%	2.96%	0.86%
Toa Alta	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Toa Baja	47.68%	16.88%	7.20%	0.06%	2.26%	25.92%
Trujillo Alto	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Utuado	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Vega Alta	90.91%	3.86%	2.29%	0.00%	2.24%	0.70%
Vega Baja	74.06%	5.51%	5.29%	3.98%	5.22%	5.96%
Vieques	55.53%	36.72%	4.76%	1.31%	0.33%	1.34%
Villalba	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Yabucoa	92.30%	7.50%	0.00%	0.02%	0.17%	0.00%
Yauco	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Table 46: Percent of (Island) Hexagonal Area by Tsunami Hazard per Municipio

Municipio	Tsunami Inundation Percent Area by Total (Island) Land Area					
	None	Low (0.1% – 20%)	Medium Low (20.1% - 40%)	Medium (40.1% - 60%)	Medium High (60.1% - 80%)	High (>80%)
Adjuntas	2.19%	0.00%	0.00%	0.00%	0.00%	0.00%
Aguada	0.73%	1.10%	2.98%	4.38%	3.70%	2.46%
Aguadilla	0.97%	2.12%	1.57%	1.73%	1.15%	0.91%
Aguas Buenas	0.98%	0.00%	0.00%	0.00%	0.00%	0.00%
Aibonito	1.02%	0.00%	0.00%	0.00%	0.00%	0.00%
Anasco	1.05%	1.66%	0.89%	2.92%	0.00%	3.97%
Arecibo	3.45%	6.55%	2.64%	5.35%	8.69%	1.93%
Arroyo	0.39%	0.70%	2.01%	0.85%	0.00%	0.17%
Barceloneta	0.38%	1.49%	2.80%	2.30%	3.61%	0.66%
Barranquitas	1.12%	0.00%	0.00%	0.00%	0.00%	0.00%
Bayamon	1.34%	1.36%	0.75%	0.00%	0.00%	0.35%
Cabo Rojo	1.55%	5.79%	8.20%	8.11%	9.93%	3.76%
Caguas	1.93%	0.00%	0.00%	0.00%	0.00%	0.00%

Camuy	1.43%	0.68%	0.72%	0.00%	1.36%	0.12%
Canovanas	0.92%	1.40%	1.87%	0.10%	1.37%	0.57%
Carolina	1.10%	2.86%	1.57%	4.79%	2.48%	6.51%
Catano	0.03%	0.13%	2.53%	1.42%	1.92%	1.71%
Cayey	1.69%	0.00%	0.00%	0.00%	0.00%	0.00%
Ceiba	0.58%	3.15%	2.56%	5.63%	3.08%	2.34%
Ciales	2.18%	0.00%	0.00%	0.00%	0.00%	0.00%
Cidra	1.19%	0.00%	0.00%	0.00%	0.00%	0.00%
Coamo	2.54%	0.00%	0.00%	0.00%	0.00%	0.00%
Comerio	0.93%	0.00%	0.00%	0.00%	0.00%	0.00%
Corozal	1.39%	0.00%	0.00%	0.00%	0.00%	0.00%
Culebra	0.06%	5.03%	2.59%	0.00%	0.00%	0.00%
Dorado	0.52%	1.30%	0.77%	4.02%	1.36%	3.75%
Fajardo	0.65%	2.89%	2.33%	2.60%	4.83%	1.04%
Florida	0.50%	0.00%	0.00%	0.00%	0.00%	0.00%
Guanica	0.94%	4.16%	3.02%	0.02%	0.30%	0.00%
Guayama	1.84%	3.01%	2.75%	0.97%	2.66%	0.52%
Guayanilla	1.21%	2.69%	0.93%	0.00%	0.00%	0.00%
Guaynabo	0.86%	0.51%	0.64%	0.00%	0.00%	0.00%
Gurabo	0.92%	0.00%	0.00%	0.00%	0.00%	0.00%
Hatillo	1.21%	1.19%	2.44%	0.76%	1.61%	0.24%
Hormigueros	0.36%	0.10%	0.00%	0.00%	0.00%	0.00%
Humacao	1.13%	2.08%	3.45%	6.73%	3.17%	1.17%
Isabela	1.55%	2.41%	3.43%	1.47%	0.00%	0.73%
Jayuya	1.45%	0.00%	0.00%	0.00%	0.00%	0.00%
Juana Diaz	1.81%	1.28%	2.10%	1.79%	1.02%	0.60%
Juncos	0.87%	0.00%	0.00%	0.00%	0.00%	0.00%
Lajas	1.70%	3.10%	3.33%	0.00%	1.41%	0.53%
Lares	2.01%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Marias	1.52%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Piedras	1.11%	0.00%	0.00%	0.00%	0.00%	0.00%
Loiza	0.02%	0.35%	0.62%	7.78%	5.15%	22.03%
Luquillo	0.62%	1.27%	3.13%	2.02%	1.41%	1.78%
Manati	1.24%	1.42%	3.67%	3.32%	4.22%	1.45%
Maricao	1.19%	0.00%	0.00%	0.00%	0.00%	0.00%
Maunabo	0.61%	1.23%	0.00%	0.00%	0.00%	0.00%
Mayaguez	2.15%	1.88%	3.26%	2.58%	0.70%	8.06%
Moca	1.64%	0.00%	0.00%	0.00%	0.00%	0.00%
Morovis	1.27%	0.00%	0.00%	0.00%	0.00%	0.00%
Naguabo	1.41%	1.73%	4.00%	1.20%	5.97%	0.38%
Naranjito	0.90%	0.00%	0.00%	0.00%	0.00%	0.00%
Orocovis	2.08%	0.00%	0.00%	0.00%	0.00%	0.00%

Patillas	1.42%	1.55%	0.61%	0.62%	0.00%	0.00%
Penuelas	1.35%	1.29%	0.02%	1.36%	0.22%	0.20%
Ponce	3.41%	2.32%	2.65%	7.83%	3.28%	3.70%
Quebradillas	0.65%	1.48%	0.26%	0.00%	0.00%	0.00%
Rincon	0.29%	1.32%	2.52%	2.72%	0.82%	0.34%
Rio Grande	1.56%	1.25%	3.41%	2.22%	4.79%	9.20%
Sabana Grande	1.17%	0.00%	0.00%	0.00%	0.00%	0.00%
Salinas	2.01%	2.57%	0.99%	1.70%	3.01%	1.48%
San German	1.78%	0.00%	0.00%	0.00%	0.00%	0.00%
San Juan	1.24%	3.40%	2.74%	1.15%	3.84%	1.65%
San Lorenzo	1.73%	0.00%	0.00%	0.00%	0.00%	0.00%
San Sebastian	2.32%	0.00%	0.00%	0.00%	0.00%	0.00%
Santa Isabel	0.90%	2.23%	1.08%	2.01%	2.71%	0.46%
Toa Alta	0.90%	0.00%	0.00%	0.00%	0.00%	0.00%
Toa Baja	0.37%	2.01%	2.84%	0.04%	1.42%	9.54%
Trujillo Alto	0.70%	0.00%	0.00%	0.00%	0.00%	0.00%
Utua	3.75%	0.00%	0.00%	0.00%	0.00%	0.00%
Vega Alta	0.82%	0.54%	1.05%	0.00%	1.65%	0.30%
Vega Baja	1.13%	1.28%	4.09%	5.42%	6.44%	4.30%
Vieques	0.96%	9.77%	4.20%	2.04%	0.47%	1.10%
Villalba	1.21%	0.00%	0.00%	0.00%	0.00%	0.00%
Yabucoa	1.67%	2.08%	0.00%	0.04%	0.25%	0.00%
Yauco	2.22%	0.34%	0.00%	0.00%	0.00%	0.00%

Table 47: Tsunami Hazard Scores and Ranks by Municipio

Municipio	Tsunami Hazard Score (Log Multiplied)		
	Total Score	Standardized Score (0-1)	Rank of Score (1-78)
Loiza	10615.7743	1	1
Rio Grande	4690.4402	0.4418	2
Toa Baja	4480.2465	0.422	3
Mayaguez	3762.7659	0.3545	4
Carolina	3263.9850	0.3075	5
Cabo Rojo	2818.2217	0.2655	6
Vega Baja	2672.2557	0.2517	7
Ponce	2110.3040	0.1988	8
Dorado	1889.4124	0.178	9
Anasco	1839.6819	0.1733	10
Arecibo	1819.8641	0.1714	11
Aguada	1545.0843	0.1455	12
Ceiba	1447.8828	0.1364	13
San Juan	1153.1737	0.1086	14

Manati	1130.6196	0.1065	15
Salinas	998.7860	0.0941	16
Fajardo	994.4713	0.0937	17
Catano	988.7064	0.0931	18
Luquillo	980.8060	0.0924	19
Humacao	939.1662	0.0885	20
Naguabo	791.5192	0.0746	21
Barceloneta	695.6450	0.0655	22
Vieques	579.5953	0.0546	23
Aguadilla	550.5881	0.0519	24
Guayama	517.3711	0.0487	25
Santa Isabel	507.9129	0.0478	26
Canovanas	401.1996	0.0378	27
Juana Diaz	398.6350	0.0376	28
Lajas	388.0023	0.0365	29
Isabela	353.5118	0.0333	30
Vega Alta	303.6024	0.0286	31
Hatillo	281.3682	0.0265	32
Rincon	274.5131	0.0259	33
Camuy	194.6023	0.0183	34
Bayamon	159.2441	0.015	35
Penuelas	129.7541	0.0122	36
Arroyo	89.2676	0.0084	37
Guanica	34.6589	0.0033	38
Yabucoa	26.1885	0.0025	39
Patillas	8.5053	0.0008	40
Culebra	3.6677	0.0003	41
Guayanilla	1.4064	0.0001	42
Guaynabo	0.8305	0.0001	42
Adjuntas	0.0000	0.0000	44
Aguas Buenas	0.0000	0.0000	44
Aibonito	0.0000	0.0000	44
Barranquitas	0.0000	0.0000	44
Caguas	0.0000	0.0000	44
Cayey	0.0000	0.0000	44
Ciales	0.0000	0.0000	44
Cidra	0.0000	0.0000	44
Coamo	0.0000	0.0000	44
Comerio	0.0000	0.0000	44
Corozal	0.0000	0.0000	44
Florida	0.0000	0.0000	44
Gurabo	0.0000	0.0000	44

Hormigueros	0.0106	0.0000	44
Jayuya	0.0000	0.0000	44
Juncos	0.0000	0.0000	44
Lares	0.0000	0.0000	44
Las Marias	0.0000	0.0000	44
Las Piedras	0.0000	0.0000	44
Maricao	0.0000	0.0000	44
Maunabo	0.1254	0.0000	44
Moca	0.0000	0.0000	44
Morovis	0.0000	0.0000	44
Naranjito	0.0000	0.0000	44
Orocovis	0.0000	0.0000	44
Quebradillas	0.4673	0.0000	44
Sabana Grande	0.0000	0.0000	44
San German	0.0000	0.0000	44
San Lorenzo	0.0000	0.0000	44
San Sebastian	0.0000	0.0000	44
Toa Alta	0.0000	0.0000	44
Trujillo Alto	0.0000	0.0000	44
Utua	0.0000	0.0000	44
Villalba	0.0000	0.0000	44
Yauco	0.0348	0.0000	44

Drought

Hazard Overview

Drought is described as "long periods of abnormal weather enough for water shortages to cause serious hydrological imbalances in the affected area". In simpler terms, a drought is a period of unusually persistent dry weather that persists long enough to cause serious problems such as damage to agriculture and rationing in the provision of potable water to the population. The severity of a drought depends on the degree of impairment in humidity levels, duration and size of the affected area.

There are four main approaches that can define a drought.

1. Meteorological Focus: a measure of deviation from normal precipitation levels. Due to climatic differences, which can be considered a drought in one country may not necessarily be a drought elsewhere.
2. Agricultural Focus: refers to the situation where the amount of moisture in the soil does not meet the needs of a particular crop.
3. Hydrological Focus: occurs when surface water sources and groundwater are below normal.
4. Socioeconomic Focus: refers to the situation that occurs when physical shortages in water supplies begin to affect people.

The main cause of any drought is lack of rain or precipitation – a phenomenon called meteorological drought. Persistent meteorological drought leads to a hydrological drought characterized by a disparity between the natural availability of water and natural water demands. In extreme cases you can get to drought. The lack of precipitation for an extended period of time can have disastrous consequences for agriculture and metropolitan areas. In some areas of the country, it does not take long as several weeks without rain to cause damage to crops. These areas must take measures on consumption savings, such as rationing.

Data and Methods

Produced jointly by the National Drought Mitigation Center (NDMC) at the University of Nebraska-Lincoln, the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Department of Agriculture (USDA), the United States Drought Monitor (USDM) provides geospatial representations of drought hazard areas for the entire US and outlying areas. The NDMC hosts the web site of the drought monitor and the associated data, and provides the map and data to NOAA, USDA and other agencies.²⁶ Polygons produced by the USDM represent areas that have had drought conditions from 2000-2019 across Puerto Rico. Each hexagonal grid was populated with the number of instances (weeks) of drought and categorized using an equal interval classification.

²⁶ <https://droughtmonitor.unl.edu/>

Hazard Frequency Analysis Results

Drought hazard is most prevalent in the south central and central island areas and radiates out along the southern coast and into the central and north central portions of the island (Figure 17). Salinas municipio, with 58 square miles) has 83% of its land area in the highest drought frequency category (Table 48, Table 49) and more than 63% of all the high drought areas across the island are also located here (Table 50). Several surrounding municipios have a majority (if not all) of their individual land area in the medium-high drought category (Table 49) and when ranking each municipio across all hazard categories by area one can easily see the most threatened areas in terms of drought (Table 51).

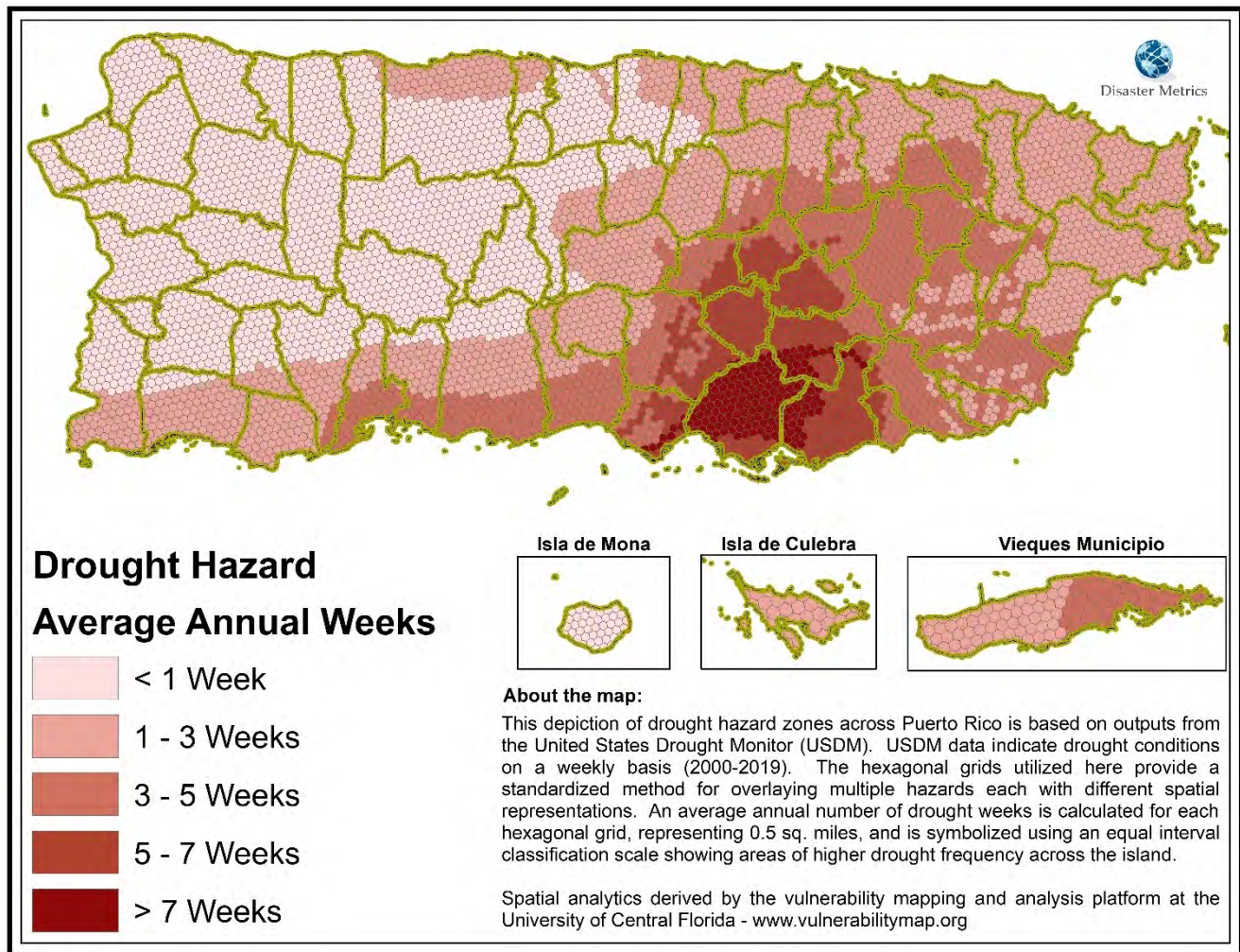


Figure 17: Drought Hazard Areas

Table 48: Drought Hazard by Municipio and Areal Extent

Municipio	HEX GRID Area by Drought Frequency (Sq. miles)				
	Low (< 1 Week)	Medium Low (1 – 3 Weeks)	Medium (3 – 5 Weeks)	Medium High (5 – 7 Weeks)	High (> 7 Weeks)
Adjuntas	67.10				

Aguada	30.92				
Aguadilla	36.61				
Aguas Buenas			28.60	1.50	
Aibonito			0.36	30.64	0.34
Anasco	39.56				
Arecibo	83.00	43.98			
Arroyo			9.61	5.44	
Barceloneta	9.58	9.18			
Barranquitas		1.76	19.65	12.88	
Bayamon		27.40	17.11		
Cabo Rojo	41.43	31.69			
Caguas		2.70	56.36		
Camuy	46.37				
Canovanas		30.86	2.15		
Cantano		29.91	17.39		
Carolina	0.02	5.06			
Cayey			11.57	28.96	11.43
Ceiba	0.00	30.37			
Ciales	47.74	18.96			
Cidra			9.52	26.93	
Coamo		10.57	38.38	27.62	1.47
Comerio			10.12	18.41	
Corozal	1.49	40.06	1.03		
Culebra	0.06	13.25			
Dorado	0.04	23.38			
Fajardo	0.35	30.16			
Florida	15.22				
Guanica	0.02	38.97	0.02		
Guayama	0.13		2.30	46.49	16.95
Guayanilla	6.71	12.99	23.29		
Guaynabo		16.11	11.66		
Gurabo		0.48	27.83		
Hatillo	39.17	2.67			
Hormigueros	11.34				
Humacao	0.01	36.22	8.87		
Isabela	55.41				
Jayuya	44.53				
Juana Diaz	0.71	20.47	39.56		
Juncos		6.74	19.87		
Lajas	11.55	49.81			
Lares	61.64				
Las Marias	46.51				

Las Piedras		19.75	14.14		
Loiza		20.53			
Luquillo	0.02	25.84			
Manati	43.30	3.52			
Maricao	36.63				
Maunabo	0.07	13.32	7.70		
Mayaguez	77.97				
Moca	50.37				
Morovis	13.52	25.40			
Naguabo	0.01	51.63	0.24		
Naranjito		8.50	17.82	1.42	
Orocovis	5.36	52.75	5.66		
Patillas	0.00	6.48	37.57	3.16	
Penuelas	9.13	24.23	11.40		
Ponce	28.82	46.52	41.64		
Quebradillas	23.14				
Rio Grande	14.39				
Rincon		60.81			
Sabana Grande	23.76	12.08			
Salinas	0.36			11.41	58.29
San German	54.48	0.03			
San Juan	0.00	43.83	5.70		
San Lorenzo		20.48	32.73		
San Sebastian	71.22				
Santa Isabel	0.11		16.30	14.01	4.15
Toa Alta	1.22	25.45	0.89		
Toa Baja		23.80			
Trujillo Alto		2.49	18.89		
Utua	115.07				
Vega Alta	11.47	16.27			
Vega Baja	29.57	17.08			
Vieques	0.03	30.46	22.69		
Villalba	0.16	36.69	0.19		
Yabucoa		14.58	40.83		
Yauco	39.32	24.22	5.28		
Grand Total	1346.72	1160.50	634.92	228.85	92.63

Table 49: Percent of (Municipio) Hexagonal Area by Drought Hazard per Municipio

Municipio	Drought Percent Area by Total (Municipio) Land Area				
	Low (< 1 Week)	Medium Low (1 – 3 Weeks)	Medium (3 – 5 Weeks)	Medium High (5 – 7 Weeks)	High (> 7 Weeks)

Adjuntas	100.00%	0.00%	0.00%	0.00%	0.00%
Aguada	100.00%	0.00%	0.00%	0.00%	0.00%
Aguadilla	100.00%	0.00%	0.00%	0.00%	0.00%
Aguas Buenas	0.00%	0.00%	95.02%	4.98%	0.00%
Aibonito	0.00%	0.00%	1.15%	97.77%	1.08%
Anasco	100.00%	0.00%	0.00%	0.00%	0.00%
Arecibo	65.36%	34.64%	0.00%	0.00%	0.00%
Arroyo	0.00%	0.00%	63.87%	36.13%	0.00%
Barceloneta	51.05%	48.95%	0.00%	0.00%	0.00%
Barranquitas	0.00%	5.13%	57.31%	37.56%	0.00%
Bayamon	0.00%	61.56%	38.44%	0.00%	0.00%
Cabo Rojo	56.66%	43.34%	0.00%	0.00%	0.00%
Caguas	0.00%	4.58%	95.42%	0.00%	0.00%
Camuy	100.00%	0.00%	0.00%	0.00%	0.00%
Canovanas	0.00%	93.49%	6.51%	0.00%	0.00%
Cantano	0.00%	63.24%	36.76%	0.00%	0.00%
Carolina	0.42%	99.58%	0.00%	0.00%	0.00%
Cayey	0.00%	0.00%	22.27%	55.73%	22.00%
Ceiba	0.02%	99.98%	0.00%	0.00%	0.00%
Ciales	71.57%	28.43%	0.00%	0.00%	0.00%
Cidra	0.00%	0.00%	26.12%	73.88%	0.00%
Coamo	0.00%	13.55%	49.18%	35.39%	1.88%
Comerio	0.00%	0.00%	35.47%	64.53%	0.00%
Corozal	3.49%	94.09%	2.42%	0.00%	0.00%
Culebra	0.44%	99.56%	0.00%	0.00%	0.00%
Dorado	0.18%	99.82%	0.00%	0.00%	0.00%
Fajardo	1.14%	98.86%	0.00%	0.00%	0.00%
Florida	100.00%	0.00%	0.00%	0.00%	0.00%
Guanica	0.06%	99.90%	0.04%	0.00%	0.00%
Guayama	0.19%	0.00%	3.48%	70.58%	25.74%
Guayanilla	15.61%	30.21%	54.18%	0.00%	0.00%
Guaynabo	0.00%	58.02%	41.98%	0.00%	0.00%
Gurabo	0.00%	1.70%	98.30%	0.00%	0.00%
Hatillo	93.62%	6.38%	0.00%	0.00%	0.00%
Hormigueros	100.00%	0.00%	0.00%	0.00%	0.00%
Humacao	0.02%	80.31%	19.66%	0.00%	0.00%
Isabela	100.00%	0.00%	0.00%	0.00%	0.00%
Jayuya	100.00%	0.00%	0.00%	0.00%	0.00%
Juana Diaz	1.17%	33.70%	65.13%	0.00%	0.00%
Juncos	0.00%	25.33%	74.67%	0.00%	0.00%
Lajas	18.83%	81.17%	0.00%	0.00%	0.00%
Lares	100.00%	0.00%	0.00%	0.00%	0.00%

Las Marias	100.00%	0.00%	0.00%	0.00%	0.00%
Las Piedras	0.00%	58.28%	41.72%	0.00%	0.00%
Loiza	0.00%	100.00%	0.00%	0.00%	0.00%
Luquillo	0.09%	99.91%	0.00%	0.00%	0.00%
Manati	92.49%	7.51%	0.00%	0.00%	0.00%
Maricao	100.00%	0.00%	0.00%	0.00%	0.00%
Maunabo	0.33%	63.16%	36.51%	0.00%	0.00%
Mayaguez	100.00%	0.00%	0.00%	0.00%	0.00%
Moca	100.00%	0.00%	0.00%	0.00%	0.00%
Morovis	34.74%	65.26%	0.00%	0.00%	0.00%
Naguabo	0.02%	99.51%	0.47%	0.00%	0.00%
Naranjito	0.00%	30.65%	64.23%	5.12%	0.00%
Orocovis	8.41%	82.71%	8.88%	0.00%	0.00%
Patillas	0.01%	13.73%	79.58%	6.69%	0.00%
Penuelas	20.41%	54.13%	25.47%	0.00%	0.00%
Ponce	24.64%	39.77%	35.59%	0.00%	0.00%
Quebradillas	100.00%	0.00%	0.00%	0.00%	0.00%
Rio Grande	100.00%	0.00%	0.00%	0.00%	0.00%
Rincon	0.00%	100.00%	0.00%	0.00%	0.00%
Sabana Grande	66.30%	33.70%	0.00%	0.00%	0.00%
Salinas	0.51%	0.00%	0.00%	16.28%	83.21%
San German	99.94%	0.06%	0.00%	0.00%	0.00%
San Juan	0.00%	88.49%	11.51%	0.00%	0.00%
San Lorenzo	0.00%	38.49%	61.51%	0.00%	0.00%
San Sebastian	100.00%	0.00%	0.00%	0.00%	0.00%
Santa Isabel	0.32%	0.00%	47.15%	40.53%	12.00%
Toa Alta	4.43%	92.34%	3.23%	0.00%	0.00%
Toa Baja	0.00%	100.00%	0.00%	0.00%	0.00%
Trujillo Alto	0.00%	11.65%	88.35%	0.00%	0.00%
Utuado	100.00%	0.00%	0.00%	0.00%	0.00%
Vega Alta	41.36%	58.64%	0.00%	0.00%	0.00%
Vega Baja	63.40%	36.60%	0.00%	0.00%	0.00%
Vieques	0.06%	57.28%	42.66%	0.00%	0.00%
Villalba	0.42%	99.06%	0.52%	0.00%	0.00%
Yabucoa	0.00%	26.31%	73.69%	0.00%	0.00%
Yauco	57.13%	35.19%	7.68%	0.00%	0.00%

Table 50: Percent of (Island) Hexagonal Area by Drought Hazard per Municipio

Municipio	Drought Percent Area by Total (Island) Land Area				
	Low (< 1 Week)	Medium Low (1 – 3 Weeks)	Medium (3 – 5 Weeks)	Medium High (5 – 7 Weeks)	High (> 7 Weeks)
Adjuntas	4.98%	0.00%	0.00%	0.00%	0.00%

Aguada	2.30%	0.00%	0.00%	0.00%	0.00%
Aguadilla	2.72%	0.00%	0.00%	0.00%	0.00%
Aguas Buenas	0.00%	0.00%	4.50%	0.66%	0.00%
Aibonito	0.00%	0.00%	0.06%	13.39%	0.36%
Anasco	2.94%	0.00%	0.00%	0.00%	0.00%
Arecibo	6.16%	3.79%	0.00%	0.00%	0.00%
Arroyo	0.00%	0.00%	1.51%	2.38%	0.00%
Barceloneta	0.71%	0.79%	0.00%	0.00%	0.00%
Barranquitas	0.00%	0.15%	3.09%	5.63%	0.00%
Bayamon	0.00%	2.36%	2.69%	0.00%	0.00%
Cabo Rojo	3.08%	2.73%	0.00%	0.00%	0.00%
Caguas	0.00%	0.23%	8.88%	0.00%	0.00%
Camuy	3.44%	0.00%	0.00%	0.00%	0.00%
Canovanas	0.00%	2.66%	0.34%	0.00%	0.00%
Cantano	0.00%	2.58%	2.74%	0.00%	0.00%
Carolina	0.00%	0.44%	0.00%	0.00%	0.00%
Cayey	0.00%	0.00%	1.82%	12.65%	12.34%
Ceiba	0.00%	2.62%	0.00%	0.00%	0.00%
Ciales	3.55%	1.63%	0.00%	0.00%	0.00%
Cidra	0.00%	0.00%	1.50%	11.77%	0.00%
Coamo	0.00%	0.91%	6.04%	12.07%	1.58%
Comerio	0.00%	0.00%	1.59%	8.04%	0.00%
Corozal	0.11%	3.45%	0.16%	0.00%	0.00%
Culebra	0.00%	1.14%	0.00%	0.00%	0.00%
Dorado	0.00%	2.01%	0.00%	0.00%	0.00%
Fajardo	0.03%	2.60%	0.00%	0.00%	0.00%
Florida	1.13%	0.00%	0.00%	0.00%	0.00%
Guanica	0.00%	3.36%	0.00%	0.00%	0.00%
Guayama	0.01%	0.00%	0.36%	20.31%	18.30%
Guayanilla	0.50%	1.12%	3.67%	0.00%	0.00%
Guaynabo	0.00%	1.39%	1.84%	0.00%	0.00%
Gurabo	0.00%	0.04%	4.38%	0.00%	0.00%
Hatillo	2.91%	0.23%	0.00%	0.00%	0.00%
Hormigueros	0.84%	0.00%	0.00%	0.00%	0.00%
Humacao	0.00%	3.12%	1.40%	0.00%	0.00%
Isabela	4.11%	0.00%	0.00%	0.00%	0.00%
Jayuya	3.31%	0.00%	0.00%	0.00%	0.00%
Juana Diaz	0.05%	1.76%	6.23%	0.00%	0.00%
Juncos	0.00%	0.58%	3.13%	0.00%	0.00%
Lajas	0.86%	4.29%	0.00%	0.00%	0.00%
Lares	4.58%	0.00%	0.00%	0.00%	0.00%
Las Marias	3.45%	0.00%	0.00%	0.00%	0.00%

Las Piedras	0.00%	1.70%	2.23%	0.00%	0.00%
Loiza	0.00%	1.77%	0.00%	0.00%	0.00%
Luquillo	0.00%	2.23%	0.00%	0.00%	0.00%
Manati	3.22%	0.30%	0.00%	0.00%	0.00%
Maricao	2.72%	0.00%	0.00%	0.00%	0.00%
Maunabo	0.01%	1.15%	1.21%	0.00%	0.00%
Mayaguez	5.79%	0.00%	0.00%	0.00%	0.00%
Moca	3.74%	0.00%	0.00%	0.00%	0.00%
Morovis	1.00%	2.19%	0.00%	0.00%	0.00%
Naguabo	0.00%	4.45%	0.04%	0.00%	0.00%
Naranjito	0.00%	0.73%	2.81%	0.62%	0.00%
Orocovis	0.40%	4.55%	0.89%	0.00%	0.00%
Patillas	0.00%	0.56%	5.92%	1.38%	0.00%
Penuelas	0.68%	2.09%	1.80%	0.00%	0.00%
Ponce	2.14%	4.01%	6.56%	0.00%	0.00%
Quebradillas	1.72%	0.00%	0.00%	0.00%	0.00%
Rio Grande	1.07%	0.00%	0.00%	0.00%	0.00%
Rincon	0.00%	5.24%	0.00%	0.00%	0.00%
Sabana Grande	1.76%	1.04%	0.00%	0.00%	0.00%
Salinas	0.03%	0.00%	0.00%	4.98%	62.93%
San German	4.05%	0.00%	0.00%	0.00%	0.00%
San Juan	0.00%	3.78%	0.90%	0.00%	0.00%
San Lorenzo	0.00%	1.76%	5.15%	0.00%	0.00%
San Sebastian	5.29%	0.00%	0.00%	0.00%	0.00%
Santa Isabel	0.01%	0.00%	2.57%	6.12%	4.48%
Toa Alta	0.09%	2.19%	0.14%	0.00%	0.00%
Toa Baja	0.00%	2.05%	0.00%	0.00%	0.00%
Trujillo Alto	0.00%	0.21%	2.98%	0.00%	0.00%
Utua	8.54%	0.00%	0.00%	0.00%	0.00%
Vega Alta	0.85%	1.40%	0.00%	0.00%	0.00%
Vega Baja	2.20%	1.47%	0.00%	0.00%	0.00%
Vieques	0.00%	2.62%	3.57%	0.00%	0.00%
Villalba	0.01%	3.16%	0.03%	0.00%	0.00%
Yabucoa	0.00%	1.26%	6.43%	0.00%	0.00%
Yauco	2.92%	2.09%	0.83%	0.00%	0.00%

Table 51: Drought Hazard Scores and Ranks by Municipio

Municipio	Drought Hazard Score (Log Multiplied)		
	Total Score	Standardized Score (0-1)	Rank of Score (1-78)
Salinas	10,245.3534	1	1
Guayama	3,912.6122	0.3819	2

Cayey	2,604.1302	0.2542	3
Santa Isabel	1,042.0473	0.1017	4
Coamo	915.3007	0.0893	5
Aibonito	717.5077	0.07	6
Cidra	596.1961	0.0582	7
Comerio	413.8881	0.0404	8
Barranquitas	312.1129	0.0305	9
Patillas	135.6640	0.0132	10
Arroyo	133.9784	0.0131	11
Caguas	100.4445	0.0098	12
Aguas Buenas	82.9991	0.0081	13
Ponce	81.7744	0.008	14
Yabucoa	74.8380	0.0073	15
Juana Diaz	73.5514	0.0072	16
Naranjito	63.6018	0.0062	17
San Lorenzo	61.4303	0.006	18
Gurabo	49.4566	0.0048	19
Vieques	45.2656	0.0044	20
Guayanilla	43.5186	0.0042	21
Carolina	35.7718	0.0035	22
Juncos	36.3701	0.0035	22
Bayamon	34.8626	0.0034	24
Trujillo Alto	33.9242	0.0033	25
Las Piedras	28.3343	0.0028	26
Penuelas	24.2849	0.0024	27
Guaynabo	23.3302	0.0023	28
Humacao	21.6914	0.0021	29
Orocovis	18.7653	0.0018	30
San Juan	17.3171	0.0017	31
Maunabo	15.8500	0.0015	32
Yauco	13.7002	0.0013	33
Rio Grande	10.0000	0.001	34
Canovanas	8.8859	0.0009	35
Naguabo	8.9185	0.0009	35
Arecibo	7.9530	0.0008	37
Corozal	8.4282	0.0008	37
Lajas	8.2910	0.0008	37
Guanica	6.4373	0.0006	40
Toa Alta	5.7747	0.0006	40
Villalba	6.3746	0.0006	40
Cabo Rojo	5.5715	0.0005	43
Ceiba	4.9936	0.0005	43

Fajardo	4.9628	0.0005	43
Dorado	3.8443	0.0004	46
Luquillo	4.2487	0.0004	46
Morovis	4.2948	0.0004	46
Toa Baja	3.9142	0.0004	46
Ciales	3.5335	0.0003	50
Loiza	3.3766	0.0003	50
Vega Alta	2.7746	0.0003	50
Vega Baja	3.0648	0.0003	50
Culebra	2.1791	0.0002	54
Sabana Grande	2.1929	0.0002	54
Barceloneta	1.5931	0.0001	56
Catano	0.8327	0.0001	56
Hatillo	0.7797	0.0001	56
Manati	0.9547	0.0001	56
Mayaguez	0.6776	0.0001	56
San Sebastian	0.6189	0.0001	56
Utuado	1.0000	0.0001	56
Adjuntas	0.5831	0	63
Aguada	0.2687	0	63
Aguadilla	0.3181	0	63
Anasco	0.3438	0	63
Camuy	0.4030	0	63
Florida	0.1323	0	63
Hormigueros	0.0986	0	63
Isabela	0.4815	0	63
Jayuya	0.3870	0	63
Lares	0.5357	0	63
Las Marias	0.4042	0	63
Maricao	0.3183	0	63
Moca	0.4377	0	63
Quebradillas	0.2011	0	63
Rincon	0.1251	0	63
San German	0.4787	0	63

Wind

Hazard Overview

Wind is “the horizontal motion of the air past a given point”.²⁷ Winds occur when there are differences in air pressure, always moving from a location with high pressure to one with relatively lower pressure. Wind speed depends on two factors: (a) the pressure difference between two areas, and (b) and the distance between those two areas. Stronger winds occur the higher the pressure difference and/or the closer the areas of high/low pressure. Wind speed is usually expressed in miles per hour or knots. The direction from which the wind is blowing is used to describe the wind. For example, “westerly winds” mean winds are blowing from the west. The wind events discussed in this assessment are non-hurricane, and non-tornadic wind events (i.e., mostly thunderstorm winds). Very few wind advisory events, sustained winds of 30-39 miles per hour (mph.) or wind gusts of 46-57 mph. occur in Puerto Rico on an annual basis.

Data and Methods

Puerto Rico has only a limited number of weather stations on the island capable of collecting crucial hourly information about temperature, fog, wind, and other atmospheric conditions. Using insufficient data coverage to determine wind hazard zones could result in both under and over-estimation of hazard areas. Because Puerto Rico’s wind sensor array is less than optimal, this assessment used hourly 10-meter u- and v- wind component data (unit:m/s) (1989-2018) obtained from ERA5 (ECMWF Atmospheric Reanalysis, the fifth generation) data. This satellite derived dataset of wind speeds has a spatial resolution of 0.25-degree latitude-longitude. The hourly windspeed at 10-meter is calculated from u- and v- wind components. As for each hexagon, the daily max hourly wind speed is determined first, then the average annual number of days that daily max hourly wind speed exceeds 30-kt is calculated.

Hazard Frequency Analysis Results

Wind hazard is a lower threat to lives, livelihoods, and infrastructure across Puerto Rico than other hazards. Most non-hurricane related wind events do not reach the threshold to cause damage, however the frequency of 30 knot winds across the island merits review. Figure 18 shows average annual frequency of 30 knot wind events over the 30-year period from 1989-2018 and indicates that areas on the western and eastern portions of the island have slightly greater frequency than the remainder of the island. Table 52 shows the land area of each municipio based on wind hazard class. Coupled with Table 53 and Table 54, we can see that Vieques, Culebra, Ceiba all have land in high wind hazard zones and Cabo Rojo and Rio Grande, Aguadilla, and Isla de Mona all have significant

²⁷ National Weather Service, Glossary, <http://w1.weather.gov/glossary/>

land area in the medium high hazard zone. Table 55 provides a standardized wind hazard score and rank for Puerto Rico’s Municipios.

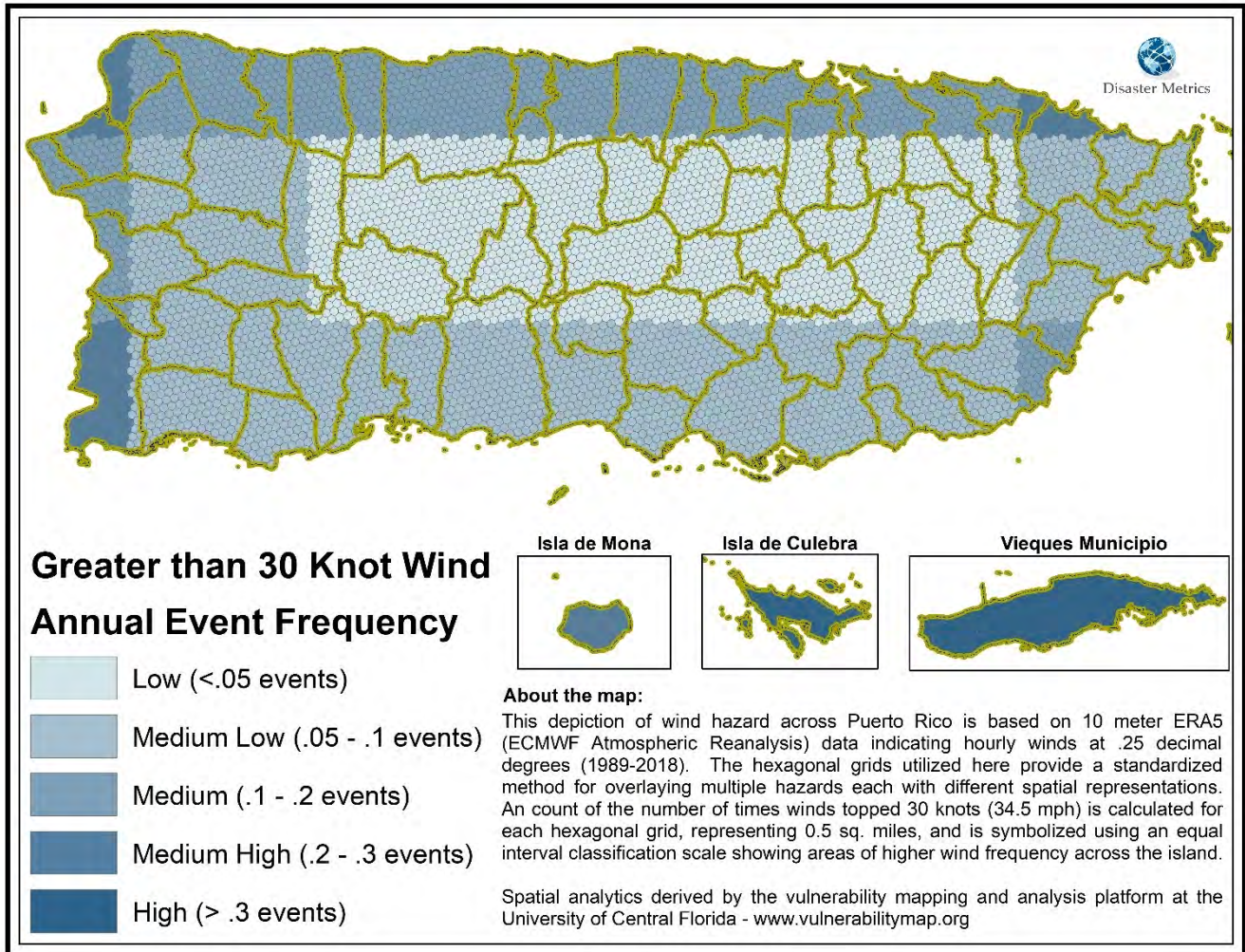


Figure 18: Wind Hazard Areas

Table 52: Wind Hazard by Municipio and Areal Extent

Municipio	HEX GRID Area by Wind Frequency (Sq. miles)				
	Low (< .05 Events)	Medium Low (.05 - .1 Events)	Medium (.1 - .2 Events)	Medium High (.2 - .3 Events)	High (> .3 events)
Adjuntas	65.57	1.53			
Aguada			22.09	8.83	
Aguadilla			18.95	17.65	
Aguas Buenas	30.10				
Aibonito	18.83	12.51			
Anasco		22.04	17.52		
Arecibo	37.77		89.21		
Arroyo		15.05			
Barceloneta			18.76		
Barranquitas	34.28				

Bayamon	29.06		15.46		
Cabo Rojo		12.74	5.38	55.00	
Caguas	57.95	1.12			
Camuy	5.92	1.27	39.18		
Canovanas	18.39	7.06	6.98	0.58	
Cantano	21.93		25.37		
Carolina			5.08		
Cayey	12.82	39.14			
Ceiba		25.41			4.96
Ciales	66.69		0.02		
Cidra	36.46				
Coamo	20.88	57.15			
Comerio	28.52				
Corozal	42.58				
Culebra					13.31
Dorado			23.42		
Fajardo		28.86		0.25	1.40
Florida	8.01		7.21		
Guanica		39.01			
Guayama		65.87			
Guayanilla	1.05	41.94			
Guaynabo	21.33		6.44		
Gurabo	28.31				
Hatillo	12.50		29.34		
Hormigueros		8.04	3.00	0.30	
Humacao		32.18	12.92		
Isabela		0.06	55.35		
Jayuya	44.53				
Juana Diaz	4.28	56.45			
Juncos	24.29	2.32			
Lajas		61.36			
Lares	37.34	24.30			
Las Marias		46.51			
Las Piedras	13.39	20.35	0.16		
Loiza			13.58	6.96	
Luquillo		24.16		1.70	
Manati	4.16		42.66		
Maricao	4.26	32.36			
Maunabo		19.49	1.60		
Mayaguez		33.54	21.66	22.18	0.59
Moca		22.46	27.40	0.51	
Morovis	38.80		0.12		

Naguabo		51.88			
Naranjito	27.75				
Orocovis	63.78				
Patillas		47.21	0.00		
Penuelas	1.23	43.53			
Ponce	18.15	98.83			
Quebradillas		0.44	22.70		
Rio Grande			14.29	0.10	
Rincon	0.15	44.77		15.90	
Sabana Grande		35.84			
Salinas		70.06			
San German		54.51			
San Juan	17.85		31.67		
San Lorenzo	35.67	17.54			
San Sebastian		64.76	6.46		
Santa Isabel		34.57			
Toa Alta	19.51		8.05		
Toa Baja			23.80		
Trujillo Alto	20.91		0.47		
Utua	115.07				
Vega Alta	5.37		22.37		
Vega Baja	3.46		43.19		
Vieques					53.18
Villalba	19.91	17.13			
Yabucoa	0.15	35.03	20.23		
Yauco	9.58	59.24			
Grand Total	1128.50	1429.63	702.10	129.96	73.44

Table 53: Percent of (Municipio) Hexagonal Area by Wind Hazard per Municipio

Municipio	Wind Percent Area by Total (Municipio) Land Area				
	Low (< .05 Events)	Medium Low (.05 - .1 Events)	Medium (.1 - .2 Events)	Medium High (.2 - .3 Events)	High (> .3 events)
Adjuntas	97.72%	2.28%	0.00%	0.00%	0.00%
Aguada	0.00%	0.00%	71.43%	28.57%	0.00%
Aguadilla	0.00%	0.00%	51.78%	48.22%	0.00%
Aguas Buenas	100.00%	0.00%	0.00%	0.00%	0.00%
Aibonito	60.07%	39.93%	0.00%	0.00%	0.00%
Anasco	0.00%	55.72%	44.28%	0.00%	0.00%
Arecibo	29.74%	0.00%	70.26%	0.00%	0.00%
Arroyo	0.00%	100.00%	0.00%	0.00%	0.00%
Barceloneta	0.00%	0.00%	100.00%	0.00%	0.00%

Barranquitas	100.00%	0.00%	0.00%	0.00%	0.00%
Bayamon	65.27%	0.00%	34.73%	0.00%	0.00%
Cabo Rojo	0.00%	17.42%	7.36%	75.22%	0.00%
Caguas	98.10%	1.90%	0.00%	0.00%	0.00%
Camuy	12.77%	2.74%	84.49%	0.00%	0.00%
Canovanas	55.71%	21.39%	21.15%	1.75%	0.00%
Cantano	46.37%	0.00%	53.63%	0.00%	0.00%
Carolina	0.00%	0.00%	100.00%	0.00%	0.00%
Cayey	24.67%	75.33%	0.00%	0.00%	0.00%
Ceiba	0.00%	83.67%	0.00%	0.00%	16.33%
Ciales	99.97%	0.00%	0.03%	0.00%	0.00%
Cidra	100.00%	0.00%	0.00%	0.00%	0.00%
Coamo	26.76%	73.24%	0.00%	0.00%	0.00%
Comerio	100.00%	0.00%	0.00%	0.00%	0.00%
Corozal	100.00%	0.00%	0.00%	0.00%	0.00%
Culebra	0.00%	0.00%	0.00%	0.00%	100.00%
Dorado	0.00%	0.00%	100.00%	0.00%	0.00%
Fajardo	0.00%	94.60%	0.00%	0.81%	4.59%
Florida	52.62%	0.00%	47.38%	0.00%	0.00%
Guanica	0.00%	100.00%	0.00%	0.00%	0.00%
Guayama	0.00%	100.00%	0.00%	0.00%	0.00%
Guayanilla	2.45%	97.55%	0.00%	0.00%	0.00%
Guaynabo	76.81%	0.00%	23.19%	0.00%	0.00%
Gurabo	100.00%	0.00%	0.00%	0.00%	0.00%
Hatillo	29.88%	0.00%	70.12%	0.00%	0.00%
Hormigueros	0.00%	70.90%	26.44%	2.66%	0.00%
Humacao	0.00%	71.36%	28.64%	0.00%	0.00%
Isabela	0.00%	0.10%	99.90%	0.00%	0.00%
Jayuya	100.00%	0.00%	0.00%	0.00%	0.00%
Juana Diaz	7.05%	92.95%	0.00%	0.00%	0.00%
Juncos	91.28%	8.72%	0.00%	0.00%	0.00%
Lajas	0.00%	100.00%	0.00%	0.00%	0.00%
Lares	60.58%	39.42%	0.00%	0.00%	0.00%
Las Marias	0.00%	100.00%	0.00%	0.00%	0.00%
Las Piedras	39.51%	60.03%	0.46%	0.00%	0.00%
Loiza	0.00%	0.00%	66.11%	33.89%	0.00%
Luquillo	0.00%	93.44%	0.00%	6.56%	0.00%
Manati	8.88%	0.00%	91.12%	0.00%	0.00%
Maricao	11.64%	88.36%	0.00%	0.00%	0.00%
Maunabo	0.00%	92.42%	7.58%	0.00%	0.00%
Mayaguez	0.00%	43.02%	27.78%	28.45%	0.75%
Moca	0.00%	44.59%	54.39%	1.02%	0.00%

Morovis	99.69%	0.00%	0.31%	0.00%	0.00%
Naguabo	0.00%	100.00%	0.00%	0.00%	0.00%
Naranjito	100.00%	0.00%	0.00%	0.00%	0.00%
Orocovis	100.00%	0.00%	0.00%	0.00%	0.00%
Patillas	0.00%	99.99%	0.01%	0.00%	0.00%
Penuelas	2.75%	97.25%	0.00%	0.00%	0.00%
Ponce	15.51%	84.49%	0.00%	0.00%	0.00%
Quebradillas	0.00%	1.89%	98.11%	0.00%	0.00%
Rjo Grande	0.00%	0.00%	99.32%	0.68%	0.00%
Rincon	0.24%	73.61%	0.00%	26.14%	0.00%
Sabana Grande	0.00%	100.00%	0.00%	0.00%	0.00%
Salinas	0.00%	100.00%	0.00%	0.00%	0.00%
San German	0.00%	100.00%	0.00%	0.00%	0.00%
San Juan	36.05%	0.00%	63.95%	0.00%	0.00%
San Lorenzo	67.04%	32.96%	0.00%	0.00%	0.00%
San Sebastian	0.00%	90.94%	9.06%	0.00%	0.00%
Santa Isabel	0.00%	100.00%	0.00%	0.00%	0.00%
Toa Alta	70.78%	0.00%	29.22%	0.00%	0.00%
Toa Baja	0.00%	0.00%	100.00%	0.00%	0.00%
Trujillo Alto	97.79%	0.00%	2.21%	0.00%	0.00%
Utuado	100.00%	0.00%	0.00%	0.00%	0.00%
Vega Alta	19.35%	0.00%	80.65%	0.00%	0.00%
Vega Baja	7.41%	0.00%	92.59%	0.00%	0.00%
Vieques	0.00%	0.00%	0.00%	0.00%	100.00%
Villalba	53.75%	46.25%	0.00%	0.00%	0.00%
Yabucoa	0.27%	63.22%	36.51%	0.00%	0.00%
Yauco	13.91%	86.09%	0.00%	0.00%	0.00%

Table 54: Percent of (Island) Hexagonal Area by Wind Hazard per Municipio

Municipio	Wind Percent Area by Total (Island) Land Area				
	Low (< .05 Events)	Medium Low (.05 - .1 Events)	Medium (.1 - .2 Events)	Medium High (.2 - .3 Events)	High (> .3 events)
Adjuntas	4.87%	0.13%	0.00%	0.00%	0.00%
Aguada	0.00%	0.00%	3.48%	3.86%	0.00%
Aguadilla	0.00%	0.00%	2.99%	7.71%	0.00%
Aguas Buenas	2.23%	0.00%	0.00%	0.00%	0.00%
Aibonito	1.40%	1.08%	0.00%	0.00%	0.00%
Anasco	0.00%	1.90%	2.76%	0.00%	0.00%
Arecibo	2.80%	0.00%	14.05%	0.00%	0.00%
Arroyo	0.00%	1.30%	0.00%	0.00%	0.00%
Barceloneta	0.00%	0.00%	2.95%	0.00%	0.00%
Barranquitas	2.55%	0.00%	0.00%	0.00%	0.00%

Bayamon	2.16%	0.00%	2.43%	0.00%	0.00%
Cabo Rojo	0.00%	1.10%	0.85%	24.03%	0.00%
Caguas	4.30%	0.10%	0.00%	0.00%	0.00%
Camuy	0.44%	0.11%	6.17%	0.00%	0.00%
Canovanas	1.37%	0.61%	1.10%	0.25%	0.00%
Cantano	1.63%	0.00%	4.00%	0.00%	0.00%
Carolina	0.00%	0.00%	0.80%	0.00%	0.00%
Cayey	0.95%	3.37%	0.00%	0.00%	0.00%
Ceiba	0.00%	2.19%	0.00%	0.00%	5.36%
Ciales	4.95%	0.00%	0.00%	0.00%	0.00%
Cidra	2.71%	0.00%	0.00%	0.00%	0.00%
Coamo	1.55%	4.92%	0.00%	0.00%	0.00%
Comerio	2.12%	0.00%	0.00%	0.00%	0.00%
Corozal	3.16%	0.00%	0.00%	0.00%	0.00%
Culebra	0.00%	0.00%	0.00%	0.00%	14.37%
Dorado	0.00%	0.00%	3.69%	0.00%	0.00%
Fajardo	0.00%	2.49%	0.00%	0.11%	1.51%
Florida	0.59%	0.00%	1.14%	0.00%	0.00%
Guanica	0.00%	3.36%	0.00%	0.00%	0.00%
Guayama	0.00%	5.68%	0.00%	0.00%	0.00%
Guayanilla	0.08%	3.61%	0.00%	0.00%	0.00%
Guaynabo	1.58%	0.00%	1.01%	0.00%	0.00%
Gurabo	2.10%	0.00%	0.00%	0.00%	0.00%
Hatillo	0.93%	0.00%	4.62%	0.00%	0.00%
Hormigueros	0.00%	0.69%	0.47%	0.13%	0.00%
Humacao	0.00%	2.77%	2.03%	0.00%	0.00%
Isabela	0.00%	0.00%	8.72%	0.00%	0.00%
Jayuya	3.31%	0.00%	0.00%	0.00%	0.00%
Juana Diaz	0.32%	4.86%	0.00%	0.00%	0.00%
Juncos	1.80%	0.20%	0.00%	0.00%	0.00%
Lajas	0.00%	5.29%	0.00%	0.00%	0.00%
Lares	2.77%	2.09%	0.00%	0.00%	0.00%
Las Marias	0.00%	4.01%	0.00%	0.00%	0.00%
Las Piedras	0.99%	1.75%	0.02%	0.00%	0.00%
Loiza	0.00%	0.00%	2.14%	3.04%	0.00%
Luquillo	0.00%	2.08%	0.00%	0.74%	0.00%
Manati	0.31%	0.00%	6.72%	0.00%	0.00%
Maricao	0.32%	2.79%	0.00%	0.00%	0.00%
Maunabo	0.00%	1.68%	0.25%	0.00%	0.00%
Mayaguez	0.00%	2.89%	3.41%	9.69%	0.64%
Moca	0.00%	1.94%	4.31%	0.22%	0.00%
Morovis	2.88%	0.00%	0.02%	0.00%	0.00%

Naguabo	0.00%	4.47%	0.00%	0.00%	0.00%
Naranjito	2.06%	0.00%	0.00%	0.00%	0.00%
Orocovis	4.74%	0.00%	0.00%	0.00%	0.00%
Patillas	0.00%	4.07%	0.00%	0.00%	0.00%
Penuelas	0.09%	3.75%	0.00%	0.00%	0.00%
Ponce	1.35%	8.52%	0.00%	0.00%	0.00%
Quebradillas	0.00%	0.04%	3.58%	0.00%	0.00%
Rio Grande	0.00%	0.00%	2.25%	0.04%	0.00%
Rincon	0.01%	3.86%	0.00%	6.95%	0.00%
Sabana Grande	0.00%	3.09%	0.00%	0.00%	0.00%
Salinas	0.00%	6.04%	0.00%	0.00%	0.00%
San German	0.00%	4.70%	0.00%	0.00%	0.00%
San Juan	1.33%	0.00%	4.99%	0.00%	0.00%
San Lorenzo	2.65%	1.51%	0.00%	0.00%	0.00%
San Sebastian	0.00%	5.58%	1.02%	0.00%	0.00%
Santa Isabel	0.00%	2.98%	0.00%	0.00%	0.00%
Toa Alta	1.45%	0.00%	1.27%	0.00%	0.00%
Toa Baja	0.00%	0.00%	3.75%	0.00%	0.00%
Trujillo Alto	1.55%	0.00%	0.07%	0.00%	0.00%
Utua	8.54%	0.00%	0.00%	0.00%	0.00%
Vega Alta	0.40%	0.00%	3.52%	0.00%	0.00%
Vega Baja	0.26%	0.00%	6.80%	0.00%	0.00%
Vieques	0.00%	0.00%	0.00%	0.00%	57.41%
Villalba	1.48%	1.48%	0.00%	0.00%	0.00%
Yabucoa	0.01%	3.02%	3.19%	0.00%	0.00%
Yauco	0.71%	5.11%	0.00%	0.00%	0.00%

Table 55: Wind Hazard Scores and Ranks by Municipio

Municipio	Wind Hazard Score (Log Multiplied)		
	Total Score	Standardized Score (0-1)	Rank of Score (1-78)
Vieques	10,000.0000	1	1
Culebra	2,502.1295	0.2502	2
Cabo Rojo	1,007.3185	0.1007	3
Ceiba	935.3059	0.0935	4
Mayaguez	541.6386	0.0541	5
Aguadilla	342.1955	0.0342	6
Rincon	293.5972	0.0293	7
Fajardo	270.9198	0.0271	8
Aguada	185.3915	0.0185	9
Loiza	141.7311	0.0141	10
Arecibo	100.3282	0.01	11

Isabela	62.0542	0.0062	12
Manati	47.8585	0.0048	13
Vega Baja	48.4455	0.0048	13
Camuy	44.0988	0.0044	15
Moca	42.3054	0.0042	16
San Juan	35.6610	0.0035	17
Hatillo	32.9946	0.0033	18
Luquillo	33.3097	0.0033	18
Cantano	28.6312	0.0028	20
Dorado	26.2499	0.0026	21
Toa Baja	26.6828	0.0026	21
Yabucoa	26.2214	0.0026	21
Quebradillas	25.4921	0.0025	24
Vega Alta	25.1267	0.0025	24
Anasco	21.8672	0.0022	26
Barceloneta	21.0282	0.0021	27
Canovanas	19.2284	0.0019	28
Rio Grande	17.7980	0.0018	29
Bayamon	17.5809	0.0017	30
Humacao	17.7381	0.0017	30
San Sebastian	13.7892	0.0014	32
Ponce	10.1577	0.001	33
Hormigueros	9.6635	0.0009	34
Toa Alta	9.1977	0.0009	34
Florida	8.1551	0.0008	36
Guaynabo	7.4028	0.0007	37
Salinas	7.0886	0.0007	37
Coamo	5.9639	0.0006	39
Guayama	6.6646	0.0006	39
Juana Diaz	5.7489	0.0006	39
Lajas	6.2089	0.0006	39
Yauco	6.0776	0.0006	39
Carolina	5.6993	0.0005	44
Naguabo	5.2494	0.0005	44
Patillas	4.7810	0.0005	44
San German	5.5153	0.0005	44
Cayey	4.0720	0.0004	48
Guanica	3.9473	0.0004	48
Guayanilla	4.2525	0.0004	48
Las Marias	4.7055	0.0004	48
Maunabo	3.7650	0.0004	48
Penuelas	4.4148	0.0004	48

Lares	2.7830	0.0003	54
Maricao	3.3116	0.0003	54
Sabana Grande	3.6266	0.0003	54
Santa Isabel	3.4983	0.0003	54
Las Piedras	2.3504	0.0002	58
San Lorenzo	2.0843	0.0002	58
Villalba	1.9062	0.0002	58
Aibonito	1.4296	0.0001	61
Arroyo	1.5225	0.0001	61
Utua	1.0000	0.0001	61
Adjuntas	0.7246	0.0000	64
Aguas Buenas	0.2615	0.0000	64
Barranquitas	0.2979	0.0000	64
Caguas	0.6169	0.0000	64
Ciales	0.6032	0.0000	64
Cidra	0.3168	0.0000	64
Comerio	0.2479	0.0000	64
Corozal	0.3700	0.0000	64
Gurabo	0.2461	0.0000	64
Jayuya	0.3870	0.0000	64
Juncos	0.4459	0.0000	64
Morovis	0.4732	0.0000	64
Naranjito	0.2411	0.0000	64
Orocovis	0.5542	0.0000	64
Trujillo Alto	0.7106	0.0000	64

Fog

Hazard Overview

Fog is a hazard to drivers, mariners, and aviators. Since 2003, three fatal plane crashes have been connected to fog events on Puerto Rico.²⁸ There are several different conditions under which fog forms. Across Puerto Rico, radiation fog is the most common type of fog. Radiation fog forms most frequently in the early morning as air near to the ground cools. When the air reaches saturation, fog will form. Initially, fog will form near or at the surface and will thicken as the air continues to cool (e.g., overnight) and also extend upward. Radiation fog mostly occurs in sheltered valleys and near bodies of water. Its appearance is usually patchy and localized since wind disrupts the development of radiation fog.²⁹ Fog in Puerto Rico dissipates quickly as air warms rapidly at daybreak.

Data and Methods

Global Historical Climatology Network (GHCN) data for Puerto Rico provided adequate information on fog hazard occurrence across eleven weather stations collecting this information between 1989-2018 (Figure 19). An island-wide depiction of daily fog frequency of occurrence was interpolated from these weather stations and summarized to the 0.5-mile hexagonal grid to provide a more nuanced understanding of fog hazard frequency across Puerto Rico.

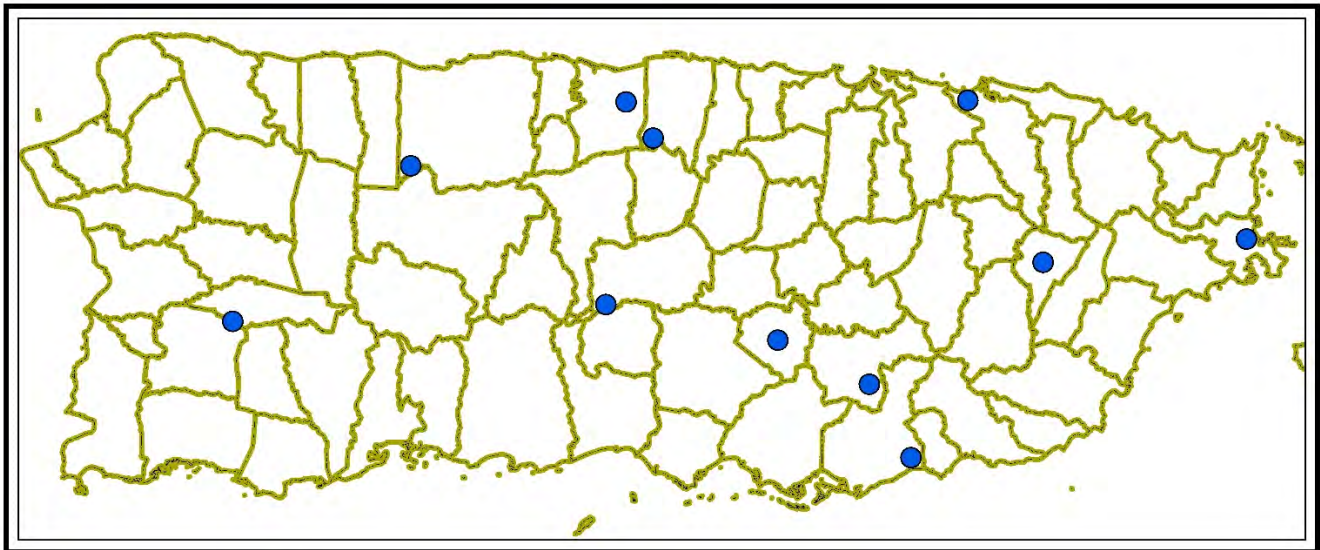


Figure 19: Weather Stations Collecting Daily Fog Hazard Information

²⁸ https://www.nts.gov/_layouts/nts.aviation/Results.aspx?queryId=cd2e02e2-52f4-43a4-8809-b5a2462b96a1

²⁹ <https://play.google.com/books/reader?id=n6MJAQAAIAAJ&hl=en&pg=GBS.PA1>

Hazard Frequency Analysis Results

Fog hazard is most frequent on eastern and northern portion of Puerto Rico with San Juan and surrounding municipios experiencing the highest average annual fog hazard occurrence. (Figure 20). Although fog is not a frequent hazard and does not cause significant damage to property and lives the spatial distribution of fog hazards affecting some places more than others should be noted (Table 56). Table 57 and Table 58 show the percentage of land area in each fog hazard class and Table 59 shows a total fog “score” and rank for each municipio across Puerto Rico.

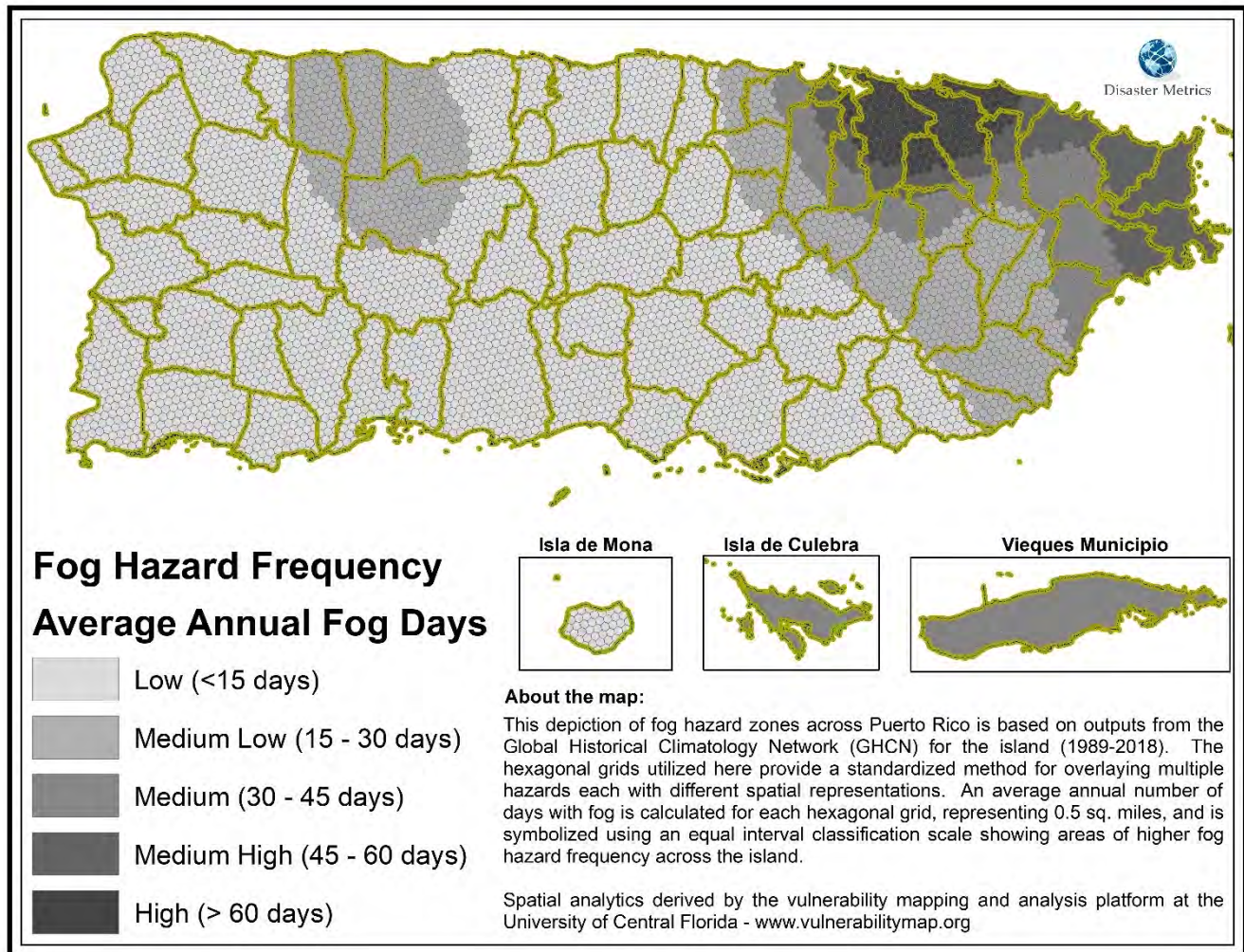


Figure 20: Fog Hazard Areas

Table 56: Fog Hazard by Municipio and Areal Extent

Municipio	HEX GRID Area by Fog Hazard Frequency (Sq. miles)				
	Low (< 16 days)	Medium Low (16 – 30 days)	Medium (31 – 45 days)	Medium High (46 – 60 days)	High (> 60 days)
Adjuntas	64.19	2.91			
Aguada	30.92				
Aguadilla	36.61				
Aguas Buenas		25.58	4.51		

Aibonito	31.34				
Anasco	39.56				
Arecibo	56.76	70.21			
Arroyo	15.05				
Barceloneta	18.76				
Barranquitas	34.28				
Bayamon		15.64	21.24	7.42	0.22
Cabo Rojo	73.12				
Caguas	2.72	40.62	14.20	1.53	
Camuy	0.12	46.25			
Canovanas		6.21	12.97	8.41	5.42
Cantano		1.35	6.52	7.26	32.17
Carolina			0.00	4.44	0.64
Cayey	51.74	0.22			
Ceiba			2.02	28.35	
Ciales	66.71				
Cidra	30.69	5.76			
Coamo	78.03				
Comerio	22.09	6.44			
Corozal	42.51	0.07			
Culebra			13.31		
Dorado	5.74	17.39	0.28		
Fajardo			0.16	30.35	
Florida	15.22				
Guanica	39.01				
Guayama	65.87				
Guayanilla	42.99				
Guaynabo		0.59	13.13	8.20	5.85
Gurabo		11.15	15.16	2.00	
Hatillo		41.84			
Hormigueros	11.34				
Humacao		19.48	25.63		
Isabela	55.41				
Jayuya	44.53				
Juana Diaz	60.73				
Juncos		26.62			
Lajas	61.36				
Lares	45.17	16.47			
Las Marias	46.51				
Las Piedras		29.58	4.31		
Loiza				6.93	13.61
Luquillo			0.98	24.88	

Manati	46.82				
Maricao	36.63				
Maunabo	4.48	16.61			
Mayaguez	77.97				
Moca	50.37				
Morovis	38.93				
Naguabo		0.30	32.11	19.48	
Naranjito	12.87	14.88			
Orocovis	63.78				
Patillas	46.27	0.95			
Penuelas	44.76				
Ponce	116.98				
Quebradillas	19.68	3.46			
Rio Grande	14.39				
Rincon			35.10	25.71	
Sabana Grande	35.84				
Salinas	70.06				
San German	54.51				
San Juan			0.88	8.06	40.58
San Lorenzo	2.14	51.07			
San Sebastian	71.18	0.04			
Santa Isabel	34.57				
Toa Alta	3.47	23.64	0.45		
Toa Baja		11.43	11.26	1.11	
Trujillo Alto			2.35	7.37	11.66
Utuado	52.73	62.34			
Vega Alta	27.74				
Vega Baja	46.65				
Vieques			53.18	0.01	
Villalba	37.04				
Yabucoa	1.71	53.70			
Yauco	68.82				
Grand Total	2269.45	622.76	269.76	191.51	110.15

Table 57: Percent of (Municipio) Hexagonal Area by Fog Hazard per Municipio

Municipio	Fog Hazard Percent Area by Total (Municipio) Land Area				
	Low (< 16 days)	Medium Low (16 – 30 days)	Medium (31 – 45 days)	Medium High (46 – 60 days)	High (> 60 days)
Adjuntas	95.67%	4.33%	0.00%	0.00%	0.00%
Aguada	100.00%	0.00%	0.00%	0.00%	0.00%
Aguadilla	100.00%	0.00%	0.00%	0.00%	0.00%

Aguas Buenas	0.00%	85.00%	15.00%	0.00%	0.00%
Aibonito	100.00%	0.00%	0.00%	0.00%	0.00%
Anasco	100.00%	0.00%	0.00%	0.00%	0.00%
Arecibo	44.70%	55.30%	0.00%	0.00%	0.00%
Arroyo	100.00%	0.00%	0.00%	0.00%	0.00%
Barceloneta	100.00%	0.00%	0.00%	0.00%	0.00%
Barranquitas	100.00%	0.00%	0.00%	0.00%	0.00%
Bayamon	0.00%	35.13%	47.70%	16.68%	0.50%
Cabo Rojo	100.00%	0.00%	0.00%	0.00%	0.00%
Caguas	4.60%	68.77%	24.05%	2.59%	0.00%
Camuy	0.27%	99.73%	0.00%	0.00%	0.00%
Canovanas	0.00%	18.81%	39.30%	25.47%	16.42%
Cantano	0.00%	2.85%	13.79%	15.34%	68.02%
Carolina	0.00%	0.00%	0.02%	87.43%	12.55%
Cayey	99.58%	0.42%	0.00%	0.00%	0.00%
Ceiba	0.00%	0.00%	6.65%	93.35%	0.00%
Ciales	100.00%	0.00%	0.00%	0.00%	0.00%
Cidra	84.19%	15.81%	0.00%	0.00%	0.00%
Coamo	100.00%	0.00%	0.00%	0.00%	0.00%
Comerio	77.43%	22.57%	0.00%	0.00%	0.00%
Corozal	99.83%	0.17%	0.00%	0.00%	0.00%
Culebra	0.00%	0.00%	100.00%	0.00%	0.00%
Dorado	24.52%	74.27%	1.22%	0.00%	0.00%
Fajardo	0.00%	0.00%	0.52%	99.48%	0.00%
Florida	100.00%	0.00%	0.00%	0.00%	0.00%
Guanica	100.00%	0.00%	0.00%	0.00%	0.00%
Guayama	100.00%	0.00%	0.00%	0.00%	0.00%
Guayanilla	100.00%	0.00%	0.00%	0.00%	0.00%
Guaynabo	0.00%	2.12%	47.27%	29.53%	21.08%
Gurabo	0.00%	39.37%	53.56%	7.07%	0.00%
Hatillo	0.00%	100.00%	0.00%	0.00%	0.00%
Hormigueros	100.00%	0.00%	0.00%	0.00%	0.00%
Humacao	0.00%	43.18%	56.82%	0.00%	0.00%
Isabela	100.00%	0.00%	0.00%	0.00%	0.00%
Jayuya	100.00%	0.00%	0.00%	0.00%	0.00%
Juana Diaz	100.00%	0.00%	0.00%	0.00%	0.00%
Juncos	0.00%	100.00%	0.00%	0.00%	0.00%
Lajas	100.00%	0.00%	0.00%	0.00%	0.00%
Lares	73.29%	26.71%	0.00%	0.00%	0.00%
Las Marias	100.00%	0.00%	0.00%	0.00%	0.00%
Las Piedras	0.00%	87.29%	12.71%	0.00%	0.00%
Loiza	0.00%	0.00%	0.00%	33.74%	66.26%

Luquillo	0.00%	0.00%	3.80%	96.20%	0.00%
Manati	100.00%	0.00%	0.00%	0.00%	0.00%
Maricao	100.00%	0.00%	0.00%	0.00%	0.00%
Maunabo	21.25%	78.75%	0.00%	0.00%	0.00%
Mayaguez	100.00%	0.00%	0.00%	0.00%	0.00%
Moca	100.00%	0.00%	0.00%	0.00%	0.00%
Morovis	100.00%	0.00%	0.00%	0.00%	0.00%
Naguabo	0.00%	0.57%	61.88%	37.55%	0.00%
Naranjito	46.37%	53.63%	0.00%	0.00%	0.00%
Orocovis	100.00%	0.00%	0.00%	0.00%	0.00%
Patillas	98.00%	2.00%	0.00%	0.00%	0.00%
Penuelas	100.00%	0.00%	0.00%	0.00%	0.00%
Ponce	100.00%	0.00%	0.00%	0.00%	0.00%
Quebradillas	85.06%	14.94%	0.00%	0.00%	0.00%
Rio Grande	100.00%	0.00%	0.00%	0.00%	0.00%
Rincon	0.00%	0.00%	57.72%	42.28%	0.00%
Sabana Grande	100.00%	0.00%	0.00%	0.00%	0.00%
Salinas	100.00%	0.00%	0.00%	0.00%	0.00%
San German	100.00%	0.00%	0.00%	0.00%	0.00%
San Juan	0.00%	0.00%	1.78%	16.28%	81.94%
San Lorenzo	4.02%	95.98%	0.00%	0.00%	0.00%
San Sebastian	99.94%	0.06%	0.00%	0.00%	0.00%
Santa Isabel	100.00%	0.00%	0.00%	0.00%	0.00%
Toa Alta	12.61%	85.76%	1.63%	0.00%	0.00%
Toa Baja	0.00%	48.02%	47.30%	4.68%	0.00%
Trujillo Alto	0.00%	0.00%	11.01%	34.45%	54.54%
Utua	45.82%	54.18%	0.00%	0.00%	0.00%
Vega Alta	100.00%	0.00%	0.00%	0.00%	0.00%
Vega Baja	100.00%	0.00%	0.00%	0.00%	0.00%
Vieques	0.00%	0.00%	99.99%	0.01%	0.00%
Villalba	100.00%	0.00%	0.00%	0.00%	0.00%
Yabucoa	3.08%	96.92%	0.00%	0.00%	0.00%
Yauco	100.00%	0.00%	0.00%	0.00%	0.00%

Table 58: Percent of (Island) Hexagonal Area by Fog Hazard per Municipio

Municipio	Fog Hazard Percent Area by Total (Island) Land Area				
	Low (< 16 days)	Medium Low (16 – 30 days)	Medium (31 – 45 days)	Medium High (46 – 60 days)	High (> 60 days)
Adjuntas	2.83%	0.47%	0.00%	0.00%	0.00%
Aguada	1.36%	0.00%	0.00%	0.00%	0.00%
Aguadilla	1.61%	0.00%	0.00%	0.00%	0.00%
Agua Buenas	0.00%	4.11%	1.67%	0.00%	0.00%

Aibonito	1.38%	0.00%	0.00%	0.00%	0.00%
Anasco	1.74%	0.00%	0.00%	0.00%	0.00%
Arecibo	2.50%	11.27%	0.00%	0.00%	0.00%
Arroyo	0.66%	0.00%	0.00%	0.00%	0.00%
Barceloneta	0.83%	0.00%	0.00%	0.00%	0.00%
Barranquitas	1.51%	0.00%	0.00%	0.00%	0.00%
Bayamon	0.00%	2.51%	7.87%	3.88%	0.20%
Cabo Rojo	3.22%	0.00%	0.00%	0.00%	0.00%
Caguas	0.12%	6.52%	5.27%	0.80%	0.00%
Camuy	0.01%	7.43%	0.00%	0.00%	0.00%
Canovanas	0.00%	1.00%	4.81%	4.39%	4.92%
Cantano	0.00%	0.22%	2.42%	3.79%	29.21%
Carolina	0.00%	0.00%	0.00%	2.32%	0.58%
Cayey	2.28%	0.04%	0.00%	0.00%	0.00%
Ceiba	0.00%	0.00%	0.75%	14.80%	0.00%
Ciales	2.94%	0.00%	0.00%	0.00%	0.00%
Cidra	1.35%	0.93%	0.00%	0.00%	0.00%
Coamo	3.44%	0.00%	0.00%	0.00%	0.00%
Comerio	0.97%	1.03%	0.00%	0.00%	0.00%
Corozal	1.87%	0.01%	0.00%	0.00%	0.00%
Culebra	0.00%	0.00%	4.93%	0.00%	0.00%
Dorado	0.25%	2.79%	0.11%	0.00%	0.00%
Fajardo	0.00%	0.00%	0.06%	15.85%	0.00%
Florida	0.67%	0.00%	0.00%	0.00%	0.00%
Guanica	1.72%	0.00%	0.00%	0.00%	0.00%
Guayama	2.90%	0.00%	0.00%	0.00%	0.00%
Guayanilla	1.89%	0.00%	0.00%	0.00%	0.00%
Guaynabo	0.00%	0.09%	4.87%	4.28%	5.31%
Gurabo	0.00%	1.79%	5.62%	1.05%	0.00%
Hatillo	0.00%	6.72%	0.00%	0.00%	0.00%
Hormigueros	0.50%	0.00%	0.00%	0.00%	0.00%
Humacao	0.00%	3.13%	9.50%	0.00%	0.00%
Isabela	2.44%	0.00%	0.00%	0.00%	0.00%
Jayuya	1.96%	0.00%	0.00%	0.00%	0.00%
Juana Diaz	2.68%	0.00%	0.00%	0.00%	0.00%
Juncos	0.00%	4.27%	0.00%	0.00%	0.00%
Lajas	2.70%	0.00%	0.00%	0.00%	0.00%
Lares	1.99%	2.64%	0.00%	0.00%	0.00%
Las Marias	2.05%	0.00%	0.00%	0.00%	0.00%
Las Piedras	0.00%	4.75%	1.60%	0.00%	0.00%
Loiza	0.00%	0.00%	0.00%	3.62%	12.35%
Luquillo	0.00%	0.00%	0.36%	12.99%	0.00%

Manati	2.06%	0.00%	0.00%	0.00%	0.00%
Maricao	1.61%	0.00%	0.00%	0.00%	0.00%
Maunabo	0.20%	2.67%	0.00%	0.00%	0.00%
Mayaguez	3.44%	0.00%	0.00%	0.00%	0.00%
Moca	2.22%	0.00%	0.00%	0.00%	0.00%
Morovis	1.72%	0.00%	0.00%	0.00%	0.00%
Naguabo	0.00%	0.05%	11.90%	10.17%	0.00%
Naranjito	0.57%	2.39%	0.00%	0.00%	0.00%
Orocovis	2.81%	0.00%	0.00%	0.00%	0.00%
Patillas	2.04%	0.15%	0.00%	0.00%	0.00%
Penuelas	1.97%	0.00%	0.00%	0.00%	0.00%
Ponce	5.15%	0.00%	0.00%	0.00%	0.00%
Quebradillas	0.87%	0.55%	0.00%	0.00%	0.00%
Rio Grande	0.63%	0.00%	0.00%	0.00%	0.00%
Rincon	0.00%	0.00%	13.01%	13.43%	0.00%
Sabana Grande	1.58%	0.00%	0.00%	0.00%	0.00%
Salinas	3.09%	0.00%	0.00%	0.00%	0.00%
San German	2.40%	0.00%	0.00%	0.00%	0.00%
San Juan	0.00%	0.00%	0.33%	4.21%	36.84%
San Lorenzo	0.09%	8.20%	0.00%	0.00%	0.00%
San Sebastian	3.14%	0.01%	0.00%	0.00%	0.00%
Santa Isabel	1.52%	0.00%	0.00%	0.00%	0.00%
Toa Alta	0.15%	3.80%	0.17%	0.00%	0.00%
Toa Baja	0.00%	1.84%	4.17%	0.58%	0.00%
Trujillo Alto	0.00%	0.00%	0.87%	3.85%	10.59%
Utua	2.32%	10.01%	0.00%	0.00%	0.00%
Vega Alta	1.22%	0.00%	0.00%	0.00%	0.00%
Vega Baja	2.06%	0.00%	0.00%	0.00%	0.00%
Vieques	0.00%	0.00%	19.71%	0.00%	0.00%
Villalba	1.63%	0.00%	0.00%	0.00%	0.00%
Yabucoa	0.08%	8.62%	0.00%	0.00%	0.00%
Yauco	3.03%	0.00%	0.00%	0.00%	0.00%

Table 59: Fog Hazard Scores and Ranks by Municipio

Municipio	Fog Hazard Score (Log Multiplied)		
	Total Score	Standardized Score (0-1)	Rank of Score (1-78)
San Juan	10,267.3169	1.0000	1
Cantano	8,180.1550	0.7967	2
Loiza	3,580.9370	0.3488	3
Trujillo Alto	3,120.9439	0.3040	4
Guaynabo	1,737.0824	0.1692	5

Canovanas	1,638.0846	0.1595	6
Fajardo	1,000.2974	0.0974	7
Ceiba	937.8861	0.0913	8
Rincon	913.1486	0.0889	9
Luquillo	821.4448	0.08	10
Naguabo	702.1844	0.0684	11
Bayamon	341.0567	0.0332	12
Carolina	303.7264	0.0296	13
Vieques	100.1823	0.0097	14
Gurabo	96.0485	0.0093	15
Caguas	82.8287	0.0081	16
Toa Baja	59.5161	0.0058	17
Humacao	50.9674	0.005	18
Culebra	25.0239	0.0024	19
Aguas Buenas	12.1312	0.0012	20
Las Piedras	12.3153	0.0012	20
Arecibo	10.4852	0.001	22
Utua	9.3299	0.0009	23
San Lorenzo	7.2917	0.0007	24
Yabucoa	7.6626	0.0007	24
Camuy	6.5878	0.0006	26
Hatillo	5.9589	0.0006	26
Juncos	3.7907	0.0004	28
Toa Alta	4.2403	0.0004	28
Dorado	3.0614	0.0003	30
Lares	2.7313	0.0003	30
Maunabo	2.4035	0.0002	32
Naranjito	2.2294	0.0002	32
Adjuntas	0.9628	0.0001	34
Cabo Rojo	0.6250	0.0001	34
Cidra	1.0834	0.0001	34
Coamo	0.6670	0.0001	34
Comerio	1.1057	0.0001	34
Mayaguez	0.6665	0.0001	34
Ponce	1.0000	0.0001	34
Quebradillas	0.6605	0.0001	34
San Sebastian	0.6142	0.0001	34
Aguada	0.2644	0.0000	43
Aguadilla	0.3129	0.0000	43
Aibonito	0.2679	0.0000	43
Anasco	0.3382	0.0000	43
Arroyo	0.1286	0.0000	43

Barceloneta	0.1604	0.0000	43
Barranquitas	0.2931	0.0000	43
Cayey	0.4734	0.0000	43
Ciales	0.5702	0.0000	43
Corozal	0.3736	0.0000	43
Florida	0.1301	0.0000	43
Guanica	0.3335	0.0000	43
Guayama	0.5631	0.0000	43
Guayanilla	0.3675	0.0000	43
Hormigueros	0.0970	0.0000	43
Isabela	0.4737	0.0000	43
Jayuya	0.3807	0.0000	43
Juana Diaz	0.5192	0.0000	43
Lajas	0.5246	0.0000	43
Las Marias	0.3975	0.0000	43
Manati	0.4002	0.0000	43
Maricao	0.3131	0.0000	43
Moca	0.4305	0.0000	43
Morovis	0.3327	0.0000	43
Orocovis	0.5452	0.0000	43
Patillas	0.5303	0.0000	43
Penuelas	0.3826	0.0000	43
Rjo Grande	0.1230	0.0000	43
Sabana Grande	0.3064	0.0000	43
Salinas	0.5989	0.0000	43
San German	0.4660	0.0000	43
Santa Isabel	0.2956	0.0000	43
Vega Alta	0.2371	0.0000	43
Vega Baja	0.3988	0.0000	43
Villalba	0.3166	0.0000	43
Yauco	0.5883	0.0000	43

Hail

Hazard Overview

An infrequent hazard in Puerto Rico, hail can occur year-round during severe thunderstorms. Hail is a precipitation type, consisting of ice pellets that form when water droplets bounce above and below the freezing level of the atmosphere. The size of hail is a function of the intensity of the updraft and hence, the severity of the storm. Strong vertical motion can keep lifting hailstones so that they continue to accumulate in size. The speed when hail reaches the ground, or its terminal velocity, is a function of its size and weight. Hail can be small, generally pea-sized. But it may be larger, capable of damaging property and killing livestock and people.

Data and Methods

The hail climatology data (1996-2018) are obtained from the Severe Weather Database, NOAA Storm Prediction Center. Although the records of the entire dataset start from 1955, the earliest records in Puerto Rico start in 1996. Start and end locations for each hail event provide a general area of impact across the island. For each hexagon, the total frequency is calculated as the number of hail events intercepting each hexagon. Annual frequency is calculated by dividing the total frequency by the number of years in record.

Hazard Frequency Analysis Results

Hail hazards occur rarely across Puerto Rico. Since 1996 only thirty-two instances of hail in Puerto Rico have been recorded by NOAA. However, a general pattern of hail events indicates that this hazard has impacted central portions of the island more than coastal areas (Figure 21). Generally, most municipios have few hail events leaving most areas of the island in lower hazard zones (Table 60) and most municipios with generally low amounts of land in high hail hazard zones (Table 61 and Table 62).

Table 63 provides an overall hail hazard score and rank for each municipio.

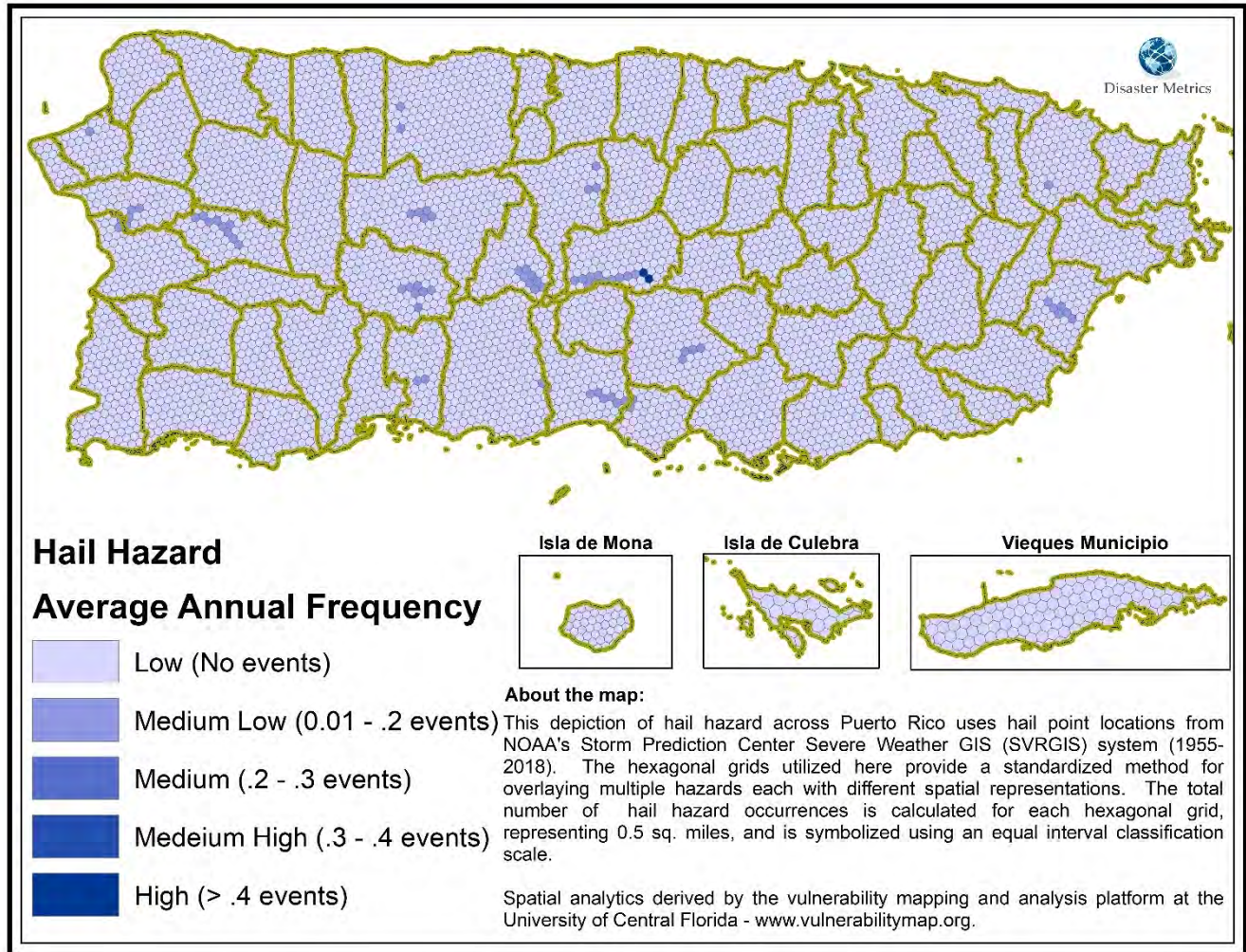


Figure 21: Hail Hazard Areas

Table 60: Hail Hazard by Municipio and Areal Extent

Municipio	HEX GRID Area by Hail Hazard Frequency (Sq. miles)				
	Low (No events)	Medium Low (.01 - .2 events)	Medium (.2 - .3 events)	Medium High (.3 - .4 events)	High (> .4 events)
Adjuntas	63.60	3.50			
Aguada	30.42	0.50			
Aguadilla	36.61				
Aguas Buenas	30.10				
Aibonito	31.34				
Anasco	37.56	2.00			
Arecibo	125.97	1.00			
Arroyo	15.05				
Barceloneta	18.76				
Barranquitas	34.28				
Bayamon	44.51				
Cabo Rojo	73.12				

Caguas	59.07			
Camuy	46.37			
Canovanas	33.01			
Cantano	47.30			
Carolina	5.08			
Cayey	51.96			
Ceiba	30.37			
Ciales	65.20	1.50		
Cidra	36.46			
Coamo	76.03	2.00		
Comerio	28.52			
Corozal	42.58			
Culebra	13.31			
Dorado	23.42			
Fajardo	30.51			
Florida	15.22			
Guanica	39.01			
Guayama	65.87			
Guayanilla	42.99			
Guaynabo	27.76			
Gurabo	28.31			
Hatillo	41.84			
Hormigueros	11.34			
Humacao	42.10	3.00		
Isabela	55.41			
Jayuya	40.54	4.00		
Juana Diaz	57.27	3.46		
Juncos	26.62			
Lajas	61.36			
Lares	61.64			
Las Marias	42.01	4.50		
Las Piedras	33.89			
Loiza	20.53			
Luquillo	25.86			
Manati	46.82			
Maricao	36.63			
Maunabo	21.09			
Mayaguez	76.97	1.00		
Moca	50.37			
Morovis	38.93			
Naguabo	51.88			
Naranjito	27.75			

Orocovis	57.54	5.23			1.00
Patillas	47.22				
Penuelas	43.76	1.00			
Ponce	116.29	0.69			
Quebradillas	23.14				
Río Grande	14.39				
Rincon	60.31	0.50			
Sabana Grande	35.84				
Salinas	70.06				
San German	54.51				
San Juan	49.53				
San Lorenzo	53.21				
San Sebastian	71.22				
Santa Isabel	33.72	0.85			
Toa Alta	27.56				
Toa Baja	23.80				
Trujillo Alto	21.38				
Utuado	112.57	2.50			
Vega Alta	27.74				
Vega Baja	46.65				
Vieques	53.18				
Villalba	36.77	0.27			
Yabucoa	55.41				
Yauco	68.82				
Grand Total	3425.13	37.50	0.00	0.00	1.00

Table 61: Percent of (Municipio) Hexagonal Area by Hail Hazard per Municipio

Municipio	Hail Hazard Percent Area by Total (Municipio) Land Area				
	Low (No events)	Medium Low (.01 - .2 events)	Medium (.2 - .3 events)	Medium High (.3 - .4 events)	High (> .4 events)
Adjuntas	94.78%	5.22%	0.00%	0.00%	0.00%
Aguada	98.38%	1.62%	0.00%	0.00%	0.00%
Aguadilla	100.00%	0.00%	0.00%	0.00%	0.00%
Aguas Buenas	100.00%	0.00%	0.00%	0.00%	0.00%
Aibonito	100.00%	0.00%	0.00%	0.00%	0.00%
Anasco	94.95%	5.05%	0.00%	0.00%	0.00%
Arecibo	99.21%	0.79%	0.00%	0.00%	0.00%
Arroyo	100.00%	0.00%	0.00%	0.00%	0.00%
Barceloneta	100.00%	0.00%	0.00%	0.00%	0.00%
Barranquitas	100.00%	0.00%	0.00%	0.00%	0.00%
Bayamon	100.00%	0.00%	0.00%	0.00%	0.00%
Cabo Rojo	100.00%	0.00%	0.00%	0.00%	0.00%

Caguas	100.00%	0.00%	0.00%	0.00%	0.00%
Camuy	100.00%	0.00%	0.00%	0.00%	0.00%
Canovanas	100.00%	0.00%	0.00%	0.00%	0.00%
Cantano	100.00%	0.00%	0.00%	0.00%	0.00%
Carolina	100.00%	0.00%	0.00%	0.00%	0.00%
Cayey	100.00%	0.00%	0.00%	0.00%	0.00%
Ceiba	100.00%	0.00%	0.00%	0.00%	0.00%
Ciales	97.75%	2.25%	0.00%	0.00%	0.00%
Cidra	100.00%	0.00%	0.00%	0.00%	0.00%
Coamo	97.44%	2.56%	0.00%	0.00%	0.00%
Comerio	100.00%	0.00%	0.00%	0.00%	0.00%
Corozal	100.00%	0.00%	0.00%	0.00%	0.00%
Culebra	100.00%	0.00%	0.00%	0.00%	0.00%
Dorado	100.00%	0.00%	0.00%	0.00%	0.00%
Fajardo	100.00%	0.00%	0.00%	0.00%	0.00%
Florida	100.00%	0.00%	0.00%	0.00%	0.00%
Guanica	100.00%	0.00%	0.00%	0.00%	0.00%
Guayama	100.00%	0.00%	0.00%	0.00%	0.00%
Guayanilla	100.00%	0.00%	0.00%	0.00%	0.00%
Guaynabo	100.00%	0.00%	0.00%	0.00%	0.00%
Gurabo	100.00%	0.00%	0.00%	0.00%	0.00%
Hatillo	100.00%	0.00%	0.00%	0.00%	0.00%
Hormigueros	100.00%	0.00%	0.00%	0.00%	0.00%
Humacao	93.35%	6.65%	0.00%	0.00%	0.00%
Isabela	100.00%	0.00%	0.00%	0.00%	0.00%
Jayuya	91.02%	8.98%	0.00%	0.00%	0.00%
Juana Diaz	94.30%	5.70%	0.00%	0.00%	0.00%
Juncos	100.00%	0.00%	0.00%	0.00%	0.00%
Lajas	100.00%	0.00%	0.00%	0.00%	0.00%
Lares	100.00%	0.00%	0.00%	0.00%	0.00%
Las Marias	90.32%	9.68%	0.00%	0.00%	0.00%
Las Piedras	100.00%	0.00%	0.00%	0.00%	0.00%
Loiza	100.00%	0.00%	0.00%	0.00%	0.00%
Luquillo	100.00%	0.00%	0.00%	0.00%	0.00%
Manati	100.00%	0.00%	0.00%	0.00%	0.00%
Maricao	100.00%	0.00%	0.00%	0.00%	0.00%
Maunabo	100.00%	0.00%	0.00%	0.00%	0.00%
Mayaguez	98.71%	1.29%	0.00%	0.00%	0.00%
Moca	100.00%	0.00%	0.00%	0.00%	0.00%
Morovis	100.00%	0.00%	0.00%	0.00%	0.00%
Naguabo	100.00%	0.00%	0.00%	0.00%	0.00%
Naranjito	100.00%	0.00%	0.00%	0.00%	0.00%

Orocovis	90.23%	8.21%	0.00%	0.00%	1.57%
Patillas	100.00%	0.00%	0.00%	0.00%	0.00%
Penuelas	97.77%	2.23%	0.00%	0.00%	0.00%
Ponce	99.41%	0.59%	0.00%	0.00%	0.00%
Quebradillas	100.00%	0.00%	0.00%	0.00%	0.00%
Río Grande	100.00%	0.00%	0.00%	0.00%	0.00%
Rincon	99.18%	0.82%	0.00%	0.00%	0.00%
Sabana Grande	100.00%	0.00%	0.00%	0.00%	0.00%
Salinas	100.00%	0.00%	0.00%	0.00%	0.00%
San German	100.00%	0.00%	0.00%	0.00%	0.00%
San Juan	100.00%	0.00%	0.00%	0.00%	0.00%
San Lorenzo	100.00%	0.00%	0.00%	0.00%	0.00%
San Sebastian	100.00%	0.00%	0.00%	0.00%	0.00%
Santa Isabel	97.53%	2.47%	0.00%	0.00%	0.00%
Toa Alta	100.00%	0.00%	0.00%	0.00%	0.00%
Toa Baja	100.00%	0.00%	0.00%	0.00%	0.00%
Trujillo Alto	100.00%	0.00%	0.00%	0.00%	0.00%
Utuado	97.83%	2.17%	0.00%	0.00%	0.00%
Vega Alta	100.00%	0.00%	0.00%	0.00%	0.00%
Vega Baja	100.00%	0.00%	0.00%	0.00%	0.00%
Vieques	100.00%	0.00%	0.00%	0.00%	0.00%
Villalba	99.28%	0.72%	0.00%	0.00%	0.00%
Yabucoa	100.00%	0.00%	0.00%	0.00%	0.00%
Yauco	100.00%	0.00%	0.00%	0.00%	0.00%

Table 62: Percent of (Island) Hexagonal Area by Hail Hazard per Municipio

Municipio	Hail Hazard Percent Area by Total (Island) Land Area				
	Low (No events)	Medium Low (.01 - .2 events)	Medium (.2 - .3 events)	Medium High (.3 - .4 events)	High (> .4 events)
Adjuntas	1.86%	9.33%	0.00%	0.00%	0.00%
Aguada	0.89%	1.33%	0.00%	0.00%	0.00%
Aguadilla	1.07%	0.00%	0.00%	0.00%	0.00%
Aguas Buenas	0.88%	0.00%	0.00%	0.00%	0.00%
Aibonito	0.91%	0.00%	0.00%	0.00%	0.00%
Anasco	1.10%	5.32%	0.00%	0.00%	0.00%
Arecibo	3.68%	2.67%	0.00%	0.00%	0.00%
Arroyo	0.44%	0.00%	0.00%	0.00%	0.00%
Barceloneta	0.55%	0.00%	0.00%	0.00%	0.00%
Barranquitas	1.00%	0.00%	0.00%	0.00%	0.00%
Bayamon	1.30%	0.00%	0.00%	0.00%	0.00%
Cabo Rojo	2.13%	0.00%	0.00%	0.00%	0.00%
Caguas	1.72%	0.00%	0.00%	0.00%	0.00%

Camuy	1.35%	0.00%	0.00%	0.00%	0.00%
Canovanas	0.96%	0.00%	0.00%	0.00%	0.00%
Cantano	1.38%	0.00%	0.00%	0.00%	0.00%
Carolina	0.15%	0.00%	0.00%	0.00%	0.00%
Cayey	1.52%	0.00%	0.00%	0.00%	0.00%
Ceiba	0.89%	0.00%	0.00%	0.00%	0.00%
Ciales	1.90%	4.01%	0.00%	0.00%	0.00%
Cidra	1.06%	0.00%	0.00%	0.00%	0.00%
Coamo	2.22%	5.33%	0.00%	0.00%	0.00%
Comerio	0.83%	0.00%	0.00%	0.00%	0.00%
Corozal	1.24%	0.00%	0.00%	0.00%	0.00%
Culebra	0.39%	0.00%	0.00%	0.00%	0.00%
Dorado	0.68%	0.00%	0.00%	0.00%	0.00%
Fajardo	0.89%	0.00%	0.00%	0.00%	0.00%
Florida	0.44%	0.00%	0.00%	0.00%	0.00%
Guanica	1.14%	0.00%	0.00%	0.00%	0.00%
Guayama	1.92%	0.00%	0.00%	0.00%	0.00%
Guayanilla	1.26%	0.00%	0.00%	0.00%	0.00%
Guaynabo	0.81%	0.00%	0.00%	0.00%	0.00%
Gurabo	0.83%	0.00%	0.00%	0.00%	0.00%
Hatillo	1.22%	0.00%	0.00%	0.00%	0.00%
Hormigueros	0.33%	0.00%	0.00%	0.00%	0.00%
Humacao	1.23%	8.00%	0.00%	0.00%	0.00%
Isabela	1.62%	0.00%	0.00%	0.00%	0.00%
Jayuya	1.18%	10.66%	0.00%	0.00%	0.00%
Juana Diaz	1.67%	9.23%	0.00%	0.00%	0.00%
Juncos	0.78%	0.00%	0.00%	0.00%	0.00%
Lajas	1.79%	0.00%	0.00%	0.00%	0.00%
Lares	1.80%	0.00%	0.00%	0.00%	0.00%
Las Marias	1.23%	12.00%	0.00%	0.00%	0.00%
Las Piedras	0.99%	0.00%	0.00%	0.00%	0.00%
Loiza	0.60%	0.00%	0.00%	0.00%	0.00%
Luquillo	0.75%	0.00%	0.00%	0.00%	0.00%
Manati	1.37%	0.00%	0.00%	0.00%	0.00%
Maricao	1.07%	0.00%	0.00%	0.00%	0.00%
Maunabo	0.62%	0.00%	0.00%	0.00%	0.00%
Mayaguez	2.25%	2.68%	0.00%	0.00%	0.00%
Moca	1.47%	0.00%	0.00%	0.00%	0.00%
Morovis	1.14%	0.00%	0.00%	0.00%	0.00%
Naguabo	1.51%	0.00%	0.00%	0.00%	0.00%
Naranjito	0.81%	0.00%	0.00%	0.00%	0.00%
Orocovis	1.68%	13.96%	0.00%	0.00%	100.00%

Patillas	1.38%	0.00%	0.00%	0.00%	0.00%
Penueles	1.28%	2.67%	0.00%	0.00%	0.00%
Ponce	3.40%	1.83%	0.00%	0.00%	0.00%
Quebradillas	0.68%	0.00%	0.00%	0.00%	0.00%
Río Grande	0.42%	0.00%	0.00%	0.00%	0.00%
Rincon	1.76%	1.33%	0.00%	0.00%	0.00%
Sabana Grande	1.05%	0.00%	0.00%	0.00%	0.00%
Salinas	2.05%	0.00%	0.00%	0.00%	0.00%
San German	1.59%	0.00%	0.00%	0.00%	0.00%
San Juan	1.45%	0.00%	0.00%	0.00%	0.00%
San Lorenzo	1.55%	0.00%	0.00%	0.00%	0.00%
San Sebastian	2.08%	0.00%	0.00%	0.00%	0.00%
Santa Isabel	0.98%	2.27%	0.00%	0.00%	0.00%
Toa Alta	0.80%	0.00%	0.00%	0.00%	0.00%
Toa Baja	0.69%	0.00%	0.00%	0.00%	0.00%
Trujillo Alto	0.62%	0.00%	0.00%	0.00%	0.00%
Utua	3.29%	6.67%	0.00%	0.00%	0.00%
Vega Alta	0.81%	0.00%	0.00%	0.00%	0.00%
Vega Baja	1.36%	0.00%	0.00%	0.00%	0.00%
Vieques	1.55%	0.00%	0.00%	0.00%	0.00%
Villalba	1.07%	0.71%	0.00%	0.00%	0.00%
Yabucoa	1.62%	0.00%	0.00%	0.00%	0.00%
Yauco	2.01%	0.00%	0.00%	0.00%	0.00%

Table 63: Hail Hazard Scores and Ranks by Municipio

Municipio	Hail Hazard Score (Log Multiplied)		
	Total Score	Standardized Score (0-1)	Rank of Score (1-78)
Orocovis	10,010.4339	1.0000	1
Las Marias	8.9038	0.0009	2
Jayuya	7.9314	0.0008	3
Adjuntas	7.1716	0.0007	4
Juana Diaz	7.0423	0.0007	4
Humacao	6.0385	0.0006	6
Utua	5.6660	0.0006	6
Anasco	4.0824	0.0004	8
Coamo	4.4083	0.0004	8
Arecibo	2.9108	0.0003	10
Ciales	3.3683	0.0003	10
Mayaguez	2.5132	0.0003	10

Penuelas	2.2306	0.0002	13
Ponce	2.2339	0.0002	13
Santa Isabel	1.8660	0.0002	13
Aguada	1.1650	0.0001	16
Cabo Rojo	0.5628	0.0001	16
Guayama	0.5028	0.0001	16
Rincon	1.4122	0.0001	16
Salinas	0.5375	0.0001	16
San Sebastian	0.5471	0.0001	16
Villalba	0.7712	0.0001	16
Yauco	0.5272	0.0001	16
Aguadilla	0.2607	0.0000	24
Aguas Buenas	0.2069	0.0000	24
Aibonito	0.2172	0.0000	24
Arroyo	0.0824	0.0000	24
Barceloneta	0.1131	0.0000	24
Barranquitas	0.2415	0.0000	24
Bayamon	0.3262	0.0000	24
Caguas	0.4465	0.0000	24
Camuy	0.3415	0.0000	24
Canovanas	0.2310	0.0000	24
Cantano	0.3492	0.0000	24
Carolina	0.0000	0.0000	24
Cayey	0.3878	0.0000	24
Ceiba	0.2092	0.0000	24
Cidra	0.2595	0.0000	24
Comerio	0.1939	0.0000	24
Corozal	0.3102	0.0000	24
Culebra	0.0680	0.0000	24
Dorado	0.1516	0.0000	24
Fajardo	0.2103	0.0000	24
Florida	0.0839	0.0000	24
Guanica	0.2806	0.0000	24
Guayanilla	0.3136	0.0000	24
Guaynabo	0.1876	0.0000	24
Gurabo	0.1921	0.0000	24
Hatillo	0.3040	0.0000	24
Hormigueros	0.0518	0.0000	24
Isabela	0.4163	0.0000	24
Juncos	0.1781	0.0000	24
Lajas	0.4655	0.0000	24
Lares	0.4678	0.0000	24

Las Piedras	0.2383	0.0000	24
Loiza	0.1278	0.0000	24
Luquillo	0.1718	0.0000	24
Manati	0.3452	0.0000	24
Maricao	0.2609	0.0000	24
Maunabo	0.1324	0.0000	24
Moca	0.3746	0.0000	24
Morovis	0.2799	0.0000	24
Naguabo	0.3871	0.0000	24
Naranjito	0.1875	0.0000	24
Patillas	0.3485	0.0000	24
Quebradillas	0.1494	0.0000	24
Rio Grande	0.0770	0.0000	24
Sabana Grande	0.2544	0.0000	24
San German	0.4088	0.0000	24
San Juan	0.3676	0.0000	24
San Lorenzo	0.3981	0.0000	24
Toa Alta	0.1859	0.0000	24
Toa Baja	0.1548	0.0000	24
Trujillo Alto	0.1348	0.0000	24
Vega Alta	0.1874	0.0000	24
Vega Baja	0.3438	0.0000	24
Vieques	0.3979	0.0000	24
Yabucoa	0.4163	0.0000	24

High Temperatures

Hazard Overview

A heat wave is an extended period of above normal temperatures over a given period of time. The World Meteorological Organization recommends the declaration of a heat wave when the daily maximum temperatures exceed the average maximum temperatures by 9 degrees Fahrenheit and last for a period of at least five days. Temperature alone is insufficient to describe the stress placed on humans as well as flora and fauna in hot weather. It is crucial to consider the effect of relative humidity since it is essential to the body's ability to perspire and cool off. Once air temperature reaches 95°F (35°C), perspiration becomes the most important manner of heat loss. Perspiration does not work if the water cannot evaporate (i.e. sweating in high relative humidity is less effective than in dry climate).

Data and Methods

A similar method to that of fog was used for high temperature data. Here, 14 stations have collected historical temperature data across the island. Linking these stations to Global Historical Climatology Network (GHCN) data for the island provided information on temperature across 14 weather stations that collected this information between 1989-2018 (Figure 22). An island-wide depiction of daily frequency of temperatures greater than 95° was interpolated from these weather stations and summarized to the 0.5 mile hexagonal grid to provide a more nuanced understanding of heat hazard frequency across Puerto Rico.

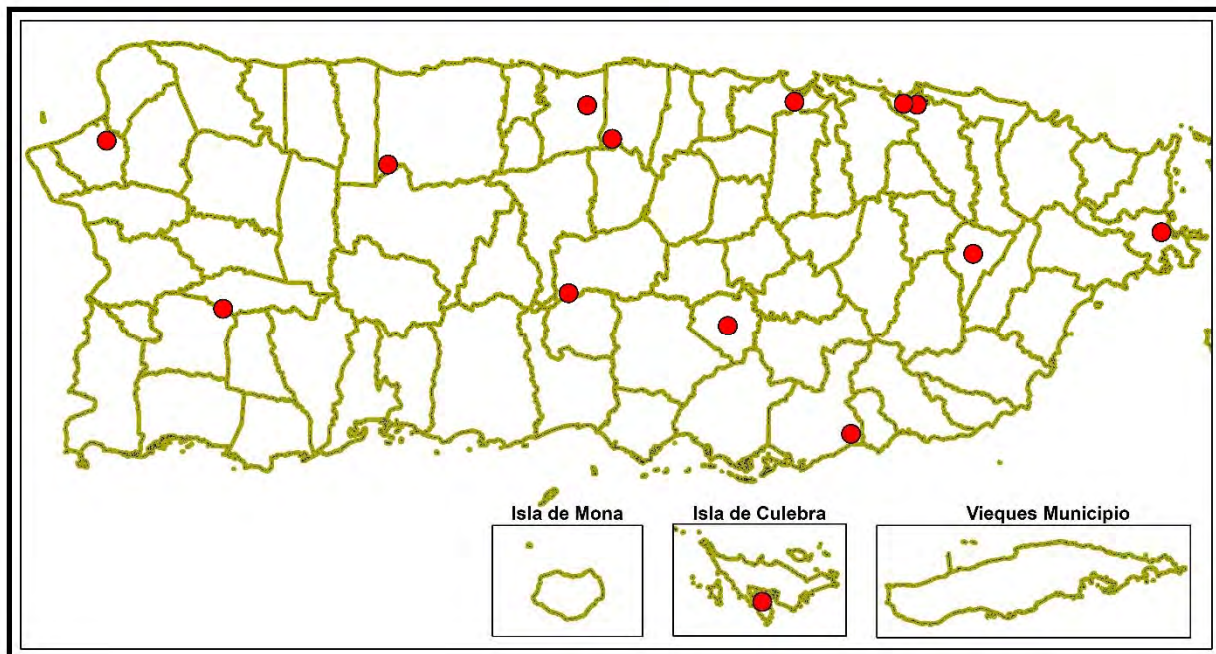


Figure 22: Weather Stations Collecting Daily Temperature Information

Hazard Frequency Analysis Results

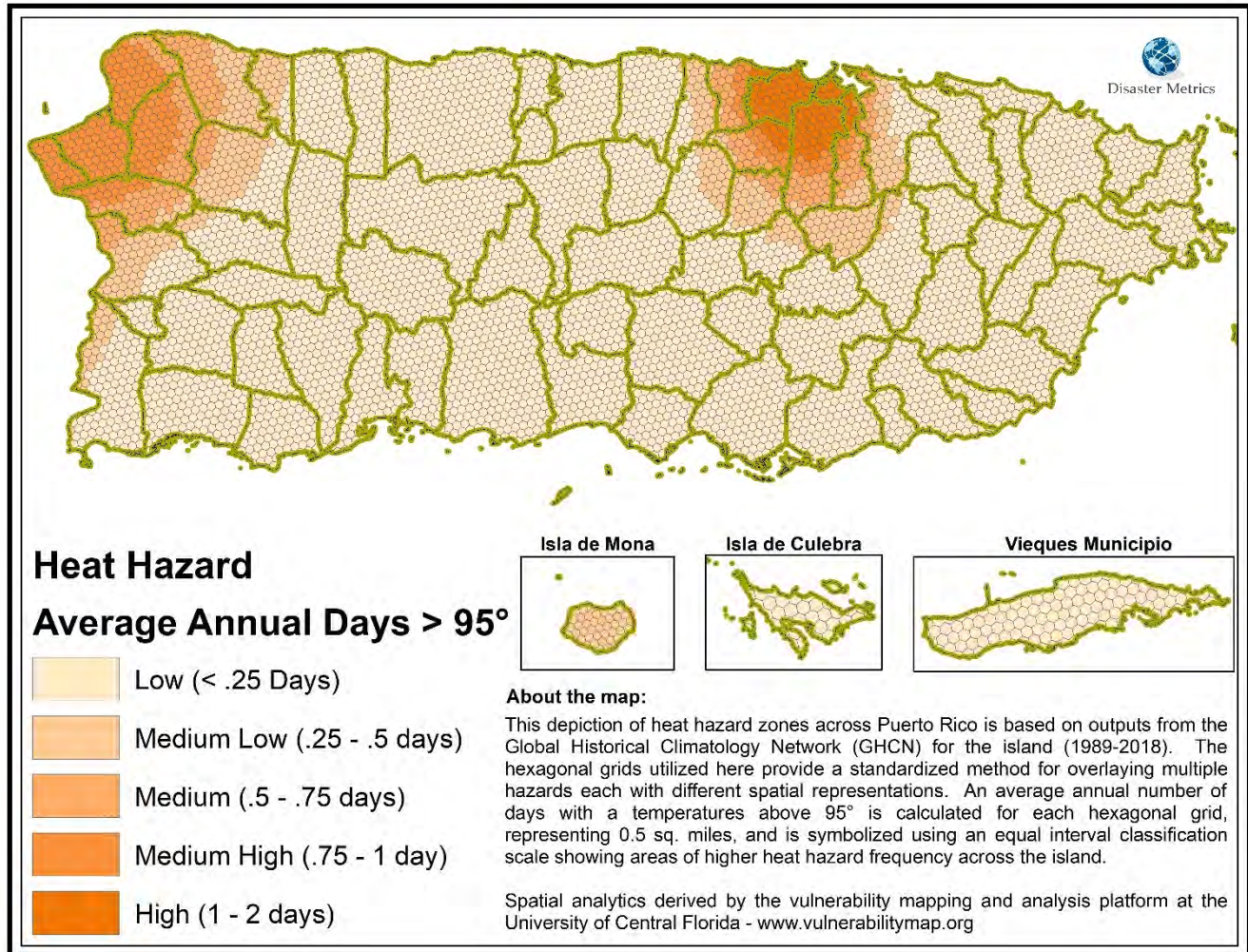


Figure 23: High Temperature Hazard Areas

Table 64: High Temperature Hazard by Municipio and Areal Extent

Municipio	HEX GRID Area by Fog Hazard Frequency (Sq. miles)				
	Low (< .25 days)	Medium Low (.25 - .5 days)	Medium (.5 - .75 days)	Medium High (.75 - 1 day)	High (>1 day)
Adjuntas	67.10				
Aguada				30.92	
Aguadilla			7.86	28.74	
Aguas Buenas	1.62	28.48			
Aibonito	31.34				
Anasco		6.52	19.83	13.21	
Arecibo	126.97				
Arroyo	15.05				
Barceloneta	18.76				
Barranquitas	34.28				

Bayamon		3.44	12.37	6.84	21.86
Cabo Rojo	57.48	15.64			
Caguas	51.71	7.36			
Camuy	46.24	0.13			
Canovanas	33.01				
Cantano	47.30				
Carolina					5.08
Cayey	51.96				
Ceiba	30.37				
Ciales	66.71				
Cidra	35.83	0.63			
Coamo	78.03				
Comerio	18.89	9.63			
Corozal	26.15	16.43			
Culebra	13.31				
Dorado		2.12	10.51	7.72	3.07
Fajardo	30.51				
Florida	15.22				
Guanica	39.01				
Guayama	65.87				
Guayanilla	42.99				
Guaynabo		7.21	10.80	5.48	4.27
Gurabo	28.31				
Hatillo	41.84				
Hormigueros	10.54	0.81			
Humacao	45.10				
Isabela	0.02	28.09	27.30		
Jayuya	44.53				
Juana Diaz	60.73				
Juncos	26.62				
Lajas	61.36				
Lares	61.64				
Las Marias	39.75	6.76			
Las Piedras	33.89				
Loiza	20.53				
Luquillo	25.86				
Manati	46.82				
Maricao	36.63				
Maunabo	21.09				
Mayaguez	20.03	49.41	8.53		
Moca		0.16	19.62	30.58	
Morovis	38.93				

Naguabo	51.88				
Naranjito	3.36	18.39	5.90	0.10	
Orocovis	63.78				
Patillas	47.22				
Penuelas	44.76				
Ponce	116.98				
Quebradillas	6.61	16.53			
Rio Grande				14.39	
Rincon	60.81				
Sabana Grande	35.84				
Salinas	70.06				
San German	54.51				
San Juan	17.10	22.68	6.47	2.82	0.45
San Lorenzo	53.21				
San Sebastian	27.70	35.06	8.45		
Santa Isabel	34.57				
Toa Alta		3.57	9.43	8.09	6.46
Toa Baja				1.03	22.77
Trujillo Alto	21.29	0.09			
Utua	115.07				
Vega Alta	11.03	15.84	0.87		
Vega Baja	45.68	0.97			
Vieques	53.18				
Villalba	37.04				
Yabucoa	55.41				
Yauco	68.82				
Grand Total	2805.83	295.93	147.95	149.94	63.98

Table 65: Percent of (Municipio) Hexagonal Area by High Temperature Hazard per Municipio

Municipio	Heat Hazard Percent Area by Total (Municipio) Land Area				
	Low (< .25 days)	Medium Low (.25 - .5 days)	Medium (.5 - .75 days)	Medium High (.75 - 1 day)	High (>1 day)
Adjuntas	100.00%	0.00%	0.00%	0.00%	0.00%
Aguada	0.00%	0.00%	0.00%	100.00%	0.00%
Aguadilla	0.00%	0.00%	21.47%	78.53%	0.00%
Aguas Buenas	5.38%	94.62%	0.00%	0.00%	0.00%
Aibonito	100.00%	0.00%	0.00%	0.00%	0.00%
Anasco	0.00%	16.48%	50.12%	33.40%	0.00%
Arecibo	100.00%	0.00%	0.00%	0.00%	0.00%
Arroyo	100.00%	0.00%	0.00%	0.00%	0.00%
Barceloneta	100.00%	0.00%	0.00%	0.00%	0.00%

Barranquitas	100.00%	0.00%	0.00%	0.00%	0.00%
Bayamon	0.00%	7.72%	27.80%	15.36%	49.12%
Cabo Rojo	78.62%	21.38%	0.00%	0.00%	0.00%
Caguas	87.54%	12.46%	0.00%	0.00%	0.00%
Camuy	99.72%	0.28%	0.00%	0.00%	0.00%
Canovanas	100.00%	0.00%	0.00%	0.00%	0.00%
Cantano	100.00%	0.00%	0.00%	0.00%	0.00%
Carolina	0.00%	0.00%	0.00%	0.00%	100.00%
Cayey	100.00%	0.00%	0.00%	0.00%	0.00%
Ceiba	100.00%	0.00%	0.00%	0.00%	0.00%
Ciales	100.00%	0.00%	0.00%	0.00%	0.00%
Cidra	98.28%	1.72%	0.00%	0.00%	0.00%
Coamo	100.00%	0.00%	0.00%	0.00%	0.00%
Comerio	66.24%	33.76%	0.00%	0.00%	0.00%
Corozal	61.42%	38.58%	0.00%	0.00%	0.00%
Culebra	100.00%	0.00%	0.00%	0.00%	0.00%
Dorado	0.00%	9.04%	44.87%	32.98%	13.11%
Fajardo	100.00%	0.00%	0.00%	0.00%	0.00%
Florida	100.00%	0.00%	0.00%	0.00%	0.00%
Guanica	100.00%	0.00%	0.00%	0.00%	0.00%
Guayama	100.00%	0.00%	0.00%	0.00%	0.00%
Guayanilla	100.00%	0.00%	0.00%	0.00%	0.00%
Guaynabo	0.00%	25.98%	38.89%	19.75%	15.37%
Gurabo	100.00%	0.00%	0.00%	0.00%	0.00%
Hatillo	100.00%	0.00%	0.00%	0.00%	0.00%
Hormigueros	92.87%	7.13%	0.00%	0.00%	0.00%
Humacao	100.00%	0.00%	0.00%	0.00%	0.00%
Isabela	0.04%	50.69%	49.27%	0.00%	0.00%
Jayuya	100.00%	0.00%	0.00%	0.00%	0.00%
Juana Diaz	100.00%	0.00%	0.00%	0.00%	0.00%
Juncos	100.00%	0.00%	0.00%	0.00%	0.00%
Lajas	100.00%	0.00%	0.00%	0.00%	0.00%
Lares	100.00%	0.00%	0.00%	0.00%	0.00%
Las Marias	85.47%	14.53%	0.00%	0.00%	0.00%
Las Piedras	100.00%	0.00%	0.00%	0.00%	0.00%
Loiza	100.00%	0.00%	0.00%	0.00%	0.00%
Luquillo	100.00%	0.00%	0.00%	0.00%	0.00%
Manati	100.00%	0.00%	0.00%	0.00%	0.00%
Maricao	100.00%	0.00%	0.00%	0.00%	0.00%
Maunabo	100.00%	0.00%	0.00%	0.00%	0.00%
Mayaguez	25.69%	63.37%	10.94%	0.00%	0.00%
Moca	0.00%	0.33%	38.96%	60.72%	0.00%

Morovis	100.00%	0.00%	0.00%	0.00%	0.00%
Naguabo	100.00%	0.00%	0.00%	0.00%	0.00%
Naranjito	12.11%	66.27%	21.27%	0.34%	0.00%
Orocovis	100.00%	0.00%	0.00%	0.00%	0.00%
Patillas	100.00%	0.00%	0.00%	0.00%	0.00%
Penuelas	100.00%	0.00%	0.00%	0.00%	0.00%
Ponce	100.00%	0.00%	0.00%	0.00%	0.00%
Quebradillas	28.59%	71.41%	0.00%	0.00%	0.00%
Rjo Grande	0.00%	0.00%	0.00%	100.00%	0.00%
Rincon	100.00%	0.00%	0.00%	0.00%	0.00%
Sabana Grande	100.00%	0.00%	0.00%	0.00%	0.00%
Salinas	100.00%	0.00%	0.00%	0.00%	0.00%
San German	100.00%	0.00%	0.00%	0.00%	0.00%
San Juan	34.52%	45.80%	13.07%	5.70%	0.91%
San Lorenzo	100.00%	0.00%	0.00%	0.00%	0.00%
San Sebastian	38.90%	49.23%	11.87%	0.00%	0.00%
Santa Isabel	100.00%	0.00%	0.00%	0.00%	0.00%
Toa Alta	0.00%	12.97%	34.21%	29.36%	23.46%
Toa Baja	0.00%	0.00%	0.00%	4.32%	95.68%
Trujillo Alto	99.57%	0.43%	0.00%	0.00%	0.00%
Utuado	100.00%	0.00%	0.00%	0.00%	0.00%
Vega Alta	39.74%	57.11%	3.15%	0.00%	0.00%
Vega Baja	97.93%	2.07%	0.00%	0.00%	0.00%
Vieques	100.00%	0.00%	0.00%	0.00%	0.00%
Villalba	100.00%	0.00%	0.00%	0.00%	0.00%
Yabucoa	100.00%	0.00%	0.00%	0.00%	0.00%
Yauco	100.00%	0.00%	0.00%	0.00%	0.00%

Table 66: Percent of (Island) Hexagonal Area by High Temperature Hazard per Municipio

Municipio	Heat Hazard Percent Area by Total (Island) Land Area				
	Low (< .25 days)	Medium Low (.25 - .5 days)	Medium (.5 – .75 days)	Medium High (.75 – 1 day)	High (>1 day)
Adjuntas	2.39%	0.00%	0.00%	0.00%	0.00%
Aguada	0.00%	0.00%	0.00%	20.63%	0.00%
Aguadilla	0.00%	0.00%	5.31%	19.17%	0.00%
Aguas Buenas	0.06%	9.62%	0.00%	0.00%	0.00%
Aibonito	1.12%	0.00%	0.00%	0.00%	0.00%
Anasco	0.00%	2.20%	13.40%	8.81%	0.00%
Arecibo	4.53%	0.00%	0.00%	0.00%	0.00%
Arroyo	0.54%	0.00%	0.00%	0.00%	0.00%
Barceloneta	0.67%	0.00%	0.00%	0.00%	0.00%

Barranquitas	1.22%	0.00%	0.00%	0.00%	0.00%
Bayamon	0.00%	1.16%	8.36%	4.56%	34.17%
Cabo Rojo	2.05%	5.28%	0.00%	0.00%	0.00%
Caguas	1.84%	2.49%	0.00%	0.00%	0.00%
Camuy	1.65%	0.04%	0.00%	0.00%	0.00%
Canovanas	1.18%	0.00%	0.00%	0.00%	0.00%
Cantano	1.69%	0.00%	0.00%	0.00%	0.00%
Carolina	0.00%	0.00%	0.00%	0.00%	7.95%
Cayey	1.85%	0.00%	0.00%	0.00%	0.00%
Ceiba	1.08%	0.00%	0.00%	0.00%	0.00%
Ciales	2.38%	0.00%	0.00%	0.00%	0.00%
Cidra	1.28%	0.21%	0.00%	0.00%	0.00%
Coamo	2.78%	0.00%	0.00%	0.00%	0.00%
Comerio	0.67%	3.25%	0.00%	0.00%	0.00%
Corozal	0.93%	5.55%	0.00%	0.00%	0.00%
Culebra	0.47%	0.00%	0.00%	0.00%	0.00%
Dorado	0.00%	0.72%	7.10%	5.15%	4.80%
Fajardo	1.09%	0.00%	0.00%	0.00%	0.00%
Florida	0.54%	0.00%	0.00%	0.00%	0.00%
Guanica	1.39%	0.00%	0.00%	0.00%	0.00%
Guayama	2.35%	0.00%	0.00%	0.00%	0.00%
Guayanilla	1.53%	0.00%	0.00%	0.00%	0.00%
Guaynabo	0.00%	2.44%	7.30%	3.66%	6.67%
Gurabo	1.01%	0.00%	0.00%	0.00%	0.00%
Hatillo	1.49%	0.00%	0.00%	0.00%	0.00%
Hormigueros	0.38%	0.27%	0.00%	0.00%	0.00%
Humacao	1.61%	0.00%	0.00%	0.00%	0.00%
Isabela	0.00%	9.49%	18.45%	0.00%	0.00%
Jayuya	1.59%	0.00%	0.00%	0.00%	0.00%
Juana Diaz	2.16%	0.00%	0.00%	0.00%	0.00%
Juncos	0.95%	0.00%	0.00%	0.00%	0.00%
Lajas	2.19%	0.00%	0.00%	0.00%	0.00%
Lares	2.20%	0.00%	0.00%	0.00%	0.00%
Las Marias	1.42%	2.28%	0.00%	0.00%	0.00%
Las Piedras	1.21%	0.00%	0.00%	0.00%	0.00%
Loiza	0.73%	0.00%	0.00%	0.00%	0.00%
Luquillo	0.92%	0.00%	0.00%	0.00%	0.00%
Manati	1.67%	0.00%	0.00%	0.00%	0.00%
Maricao	1.31%	0.00%	0.00%	0.00%	0.00%
Maunabo	0.75%	0.00%	0.00%	0.00%	0.00%
Mayaguez	0.71%	16.70%	5.77%	0.00%	0.00%
Moca	0.00%	0.06%	13.26%	20.40%	0.00%

Morovis	1.39%	0.00%	0.00%	0.00%	0.00%
Naguabo	1.85%	0.00%	0.00%	0.00%	0.00%
Naranjito	0.12%	6.21%	3.99%	0.06%	0.00%
Orocovis	2.27%	0.00%	0.00%	0.00%	0.00%
Patillas	1.68%	0.00%	0.00%	0.00%	0.00%
Penuelas	1.60%	0.00%	0.00%	0.00%	0.00%
Ponce	4.17%	0.00%	0.00%	0.00%	0.00%
Quebradillas	0.24%	5.58%	0.00%	0.00%	0.00%
Rjo Grande	0.00%	0.00%	0.00%	9.60%	0.00%
Rincon	2.17%	0.00%	0.00%	0.00%	0.00%
Sabana Grande	1.28%	0.00%	0.00%	0.00%	0.00%
Salinas	2.50%	0.00%	0.00%	0.00%	0.00%
San German	1.94%	0.00%	0.00%	0.00%	0.00%
San Juan	0.61%	7.66%	4.38%	1.88%	0.70%
San Lorenzo	1.90%	0.00%	0.00%	0.00%	0.00%
San Sebastian	0.99%	11.85%	5.71%	0.00%	0.00%
Santa Isabel	1.23%	0.00%	0.00%	0.00%	0.00%
Toa Alta	0.00%	1.21%	6.37%	5.40%	10.11%
Toa Baja	0.00%	0.00%	0.00%	0.69%	35.60%
Trujillo Alto	0.76%	0.03%	0.00%	0.00%	0.00%
Utuado	4.10%	0.00%	0.00%	0.00%	0.00%
Vega Alta	0.39%	5.35%	0.59%	0.00%	0.00%
Vega Baja	1.63%	0.33%	0.00%	0.00%	0.00%
Vieques	1.90%	0.00%	0.00%	0.00%	0.00%
Villalba	1.32%	0.00%	0.00%	0.00%	0.00%
Yabucoa	1.97%	0.00%	0.00%	0.00%	0.00%
Yauco	2.45%	0.00%	0.00%	0.00%	0.00%

Table 67: High Temperature Hazard Scores and Ranks by Municipio

Municipio	Heat Hazard Score (Log Multiplied)		
	Total Score	Standardized Score (0-1)	Rank of Score (1-78)
Toa Baja	10,033.2729	1.0000	1
Bayamon	9,867.2373	0.9835	2
Toa Alta	3,135.5668	0.3125	3
Carolina	2,232.4417	0.2225	4
Guaynabo	2,092.2208	0.2085	5
Dorado	1,637.0938	0.1632	6
Moca	1,060.7565	0.1057	7
Aguada	1,000.0000	0.0997	8
Aguadilla	958.3078	0.0955	9
Anasco	501.2276	0.0499	10

Río Grande	465.3139	0.0464	11
San Juan	317.6753	0.0317	12
Isabela	105.6851	0.0105	13
Mayaguez	41.4158	0.0041	14
San Sebastian	38.2831	0.0038	15
Naranjito	28.4585	0.0028	16
Aguas Buenas	5.7762	0.0006	17
Vega Alta	6.4916	0.0006	17
Cabo Rojo	3.6174	0.0004	19
Corozal	3.5306	0.0003	20
Quebradillas	3.3967	0.0003	20
Caguas	1.8972	0.0002	22
Comerio	2.0978	0.0002	22
Las Marias	1.6805	0.0002	22
Arecibo	1.0000	0.0001	25
Coamo	0.6145	0.0001	25
Ponce	0.9213	0.0001	25
Utua	0.9062	0.0001	25
Adjuntas	0.5284	0	29
Aibonito	0.2468	0	29
Arroyo	0.1185	0	29
Barceloneta	0.1477	0	29
Barranquitas	0.2700	0	29
Camuy	0.3904	0	29
Canovanas	0.2599	0	29
Cantano	0.3725	0	29
Cayey	0.4092	0	29
Ceiba	0.2392	0	29
Ciales	0.5254	0	29
Cidra	0.4092	0	29
Culebra	0.1048	0	29
Fajardo	0.2403	0	29
Florida	0.1199	0	29
Guanica	0.3072	0	29
Guayama	0.5187	0	29
Guayanilla	0.3386	0	29
Gurabo	0.2230	0	29
Hatillo	0.3295	0	29
Hormigueros	0.2467	0	29
Humacao	0.3552	0	29
Jayuya	0.3507	0	29
Juana Diaz	0.4783	0	29

Juncos	0.2096	0	29
Lajas	0.4833	0	29
Lares	0.4854	0	29
Las Piedras	0.2669	0	29
Loiza	0.1617	0	29
Luquillo	0.2037	0	29
Manati	0.3687	0	29
Maricao	0.2885	0	29
Maunabo	0.1661	0	29
Morovis	0.3066	0	29
Naguabo	0.4086	0	29
Orocovis	0.5023	0	29
Patillas	0.3718	0	29
Penuelas	0.3525	0	29
Rincon	0.4789	0	29
Sabana Grande	0.2823	0	29
Salinas	0.5518	0	29
San German	0.4293	0.0000	29
San Lorenzo	0.4190	0.0000	29
Santa Isabel	0.2723	0.0000	29
Trujillo Alto	0.1862	0.0000	29
Vega Baja	0.5554	0.0000	29
Vieques	0.4188	0.0000	29
Villalba	0.2917	0.0000	29
Yabucoa	0.4364	0.0000	29
Yauco	0.5420	0.0000	29

Tornado

Hazard Overview

A tornado is a violent windstorm characterized by a twisting, funnel-shaped cloud extending to the ground. It is most often generated by a thunderstorm and produced when cool, dry air intersects and overrides a layer of warm, moist air forcing the warm air to rise rapidly. The damage from a tornado is a result of high wind velocity and wind-blown debris, although they are commonly accompanied by large hail as well. Tornadoes very rarely occur on Puerto Rico. Between 1959-2019 there have been only 32 confirmed tornadoes across the island.³⁰ However infrequent, tornadoes can cause serious damage when they do occur. Tornadoes are characterized by intensity linked to post-disaster damages. Since 2007, the intensity of tornadoes is measured by the Enhanced Fujita-Pearson Scale (Table 13). The most violent tornadoes have rotating winds of 200 miles per hour or more and can cause extreme destruction, including uprooting trees and well-made structures, and turning normally harmless objects into deadly missiles.

Data and Methods

Pinpointing past tornado occurrence provides a very limited understanding of tornado frequency and likely underestimates tornado threats. Utilizing tornado watch boxes, those areas where conditions were favorable for tornado development, provides a more nuanced understanding of historical hazard zones. For this assessment tornado warning polygons (2002-2019) were obtained from National Weather Service Watches and Warnings through the Iowa Environmental Mesonet (IEM). A total frequency is calculated for each hexagonal grid as the number of tornado warning polygons that intersect each hexagon. Average annual frequency is then calculated by dividing the total frequency by the number of years in record.

Hazard Frequency Analysis Results

Western portions of the island have historically had the largest number of tornado watches and warnings (Figure 24). Table 68 indicates that San Sebastian, Mayaguez, Anasco and Las Marias all have area in the high hazard class for tornadoes. Table 69 and Table 70 further describe the total municipio and island wide percent of land area by tornado class. Here we see that San Sebastian has both a high municipio percentage of land area in high tornado hazard zones and a high island wide land area in high tornado hazard zone. Finally, Table 71 scores and ranks historical tornado frequency by municipio.

³⁰ <https://www.spc.noaa.gov/gis/svrgis/>

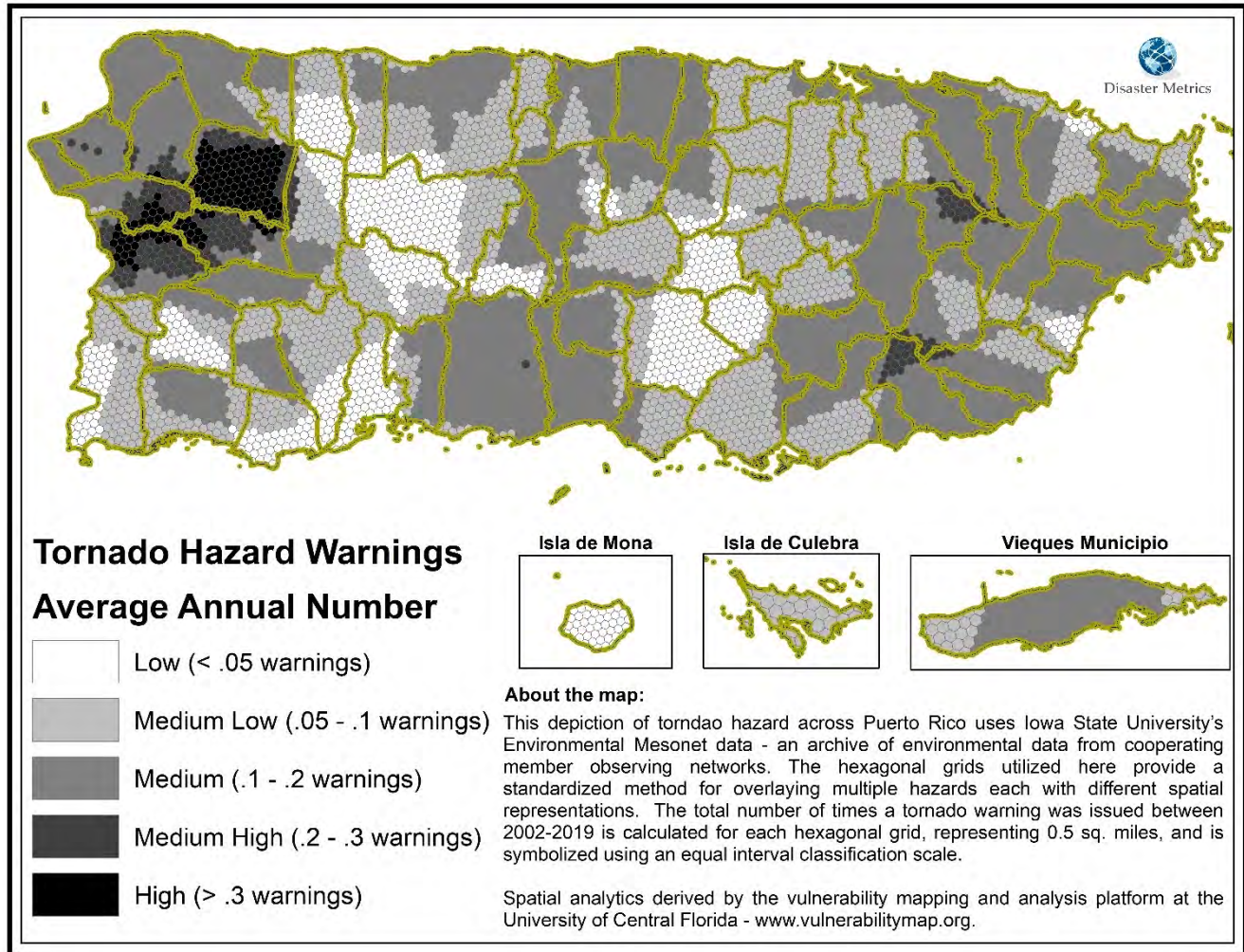


Figure 24: Tornado Hazard Areas

Table 68: Tornado Hazard by Municipio and Areal Extent

Municipio	HEX GRID Area by Tornado Warning Hazard Frequency (Sq. miles)				
	Low (< .05 warnings)	Medium Low (.05 - .1 warnings)	Medium (.1 - .2 warnings)	Medium High (.2 - .3 warnings)	High (>.3 warnings)
Adjuntas	30.42	34.88	1.79		
Aguada			28.64	2.29	
Aguadilla			36.46	0.14	
Aguas Buenas		8.70	21.40		
Aibonito	25.14	5.89	0.31		
Anasco		1.21	14.97	14.44	8.95
Arecibo	8.70	60.14	58.13		
Arroyo		2.37	12.68	0.00	
Barceloneta	0.01	17.43	1.31		
Barranquitas	29.17	5.11			
Bayamon		40.11	4.40		

Cabo Rojo	25.67	46.45	1.00		
Caguas		0.15	58.92		
Camuy	26.04	18.56	1.72	0.05	
Canovanas			31.87	1.14	
Cantano			45.51	1.80	
Carolina		0.74	4.35		
Cayey		0.52	51.19	0.26	
Ceiba	2.67	9.00	18.70		
Ciales	4.45	12.54	49.72		
Cidra	0.03	29.68	6.74		
Coamo	55.80	19.96	2.27		
Comerio	0.42	26.55	1.56		
Corozal	6.90	18.21	17.47		
Culebra	0.65	12.66			
Dorado		22.34	1.07		
Fajardo	2.25	10.31	17.95		
Florida		10.18	5.05		
Guanica	21.73	16.49	0.79		
Guayama		33.64	32.16	0.06	
Guayanilla	34.32	8.67			
Guaynabo		23.31	4.45		
Gurabo			18.33	9.99	
Hatillo	10.66	19.62	11.56		
Hormigueros	0.72	10.60	0.03		
Humacao	8.14	10.74	26.22		
Isabela		7.29	48.06	0.06	
Jayuya	14.89	11.45	18.03	0.16	
Juana Diaz	0.12	4.66	55.71	0.25	
Juncos		1.31	23.83	1.48	
Lajas	1.29	31.89	28.18		
Lares	13.47	29.51	12.85	5.82	0.00
Las Marias		1.14	14.06	19.42	11.89
Las Piedras		8.86	25.03		
Loiza		7.16	13.37		
Luquillo	0.15	10.22	15.49		
Manati		12.98	33.84		
Maricao		6.98	29.62	0.03	
Maunabo			21.09		
Mayaguez	22.77	4.04	13.00	25.14	13.02
Moca			40.96	7.68	1.73
Morovis	3.55	12.29	23.08		
Naguabo		0.39	51.49		

Naranjito	3.32	22.43	2.00		
Orocovis	0.27	43.03	20.04	0.44	
Patillas	0.00	0.16	37.10	9.96	
Penuelas	5.76	11.77	27.22		
Ponce	1.05	6.05	109.23	0.65	
Quebradillas	0.08	9.96	13.02	0.07	
Rio Grande		0.09	14.30		
Rincon	6.31	26.62	27.88		
Sabana Grande		16.91	18.93		
Salinas	0.11	58.51	11.43		
San German	22.25	18.08	14.18		
San Juan		32.34	17.19		
San Lorenzo		19.52	29.24	4.44	
San Sebastian	0.04	2.01	5.40	14.35	49.41
Santa Isabel	0.33	24.42	9.82		
Toa Alta		26.79	0.77		
Toa Baja		19.01	4.80		
Trujillo Alto		7.95	11.33	2.10	
Utua	78.13	35.24	1.71		
Vega Alta		1.55	26.19		
Vega Baja		0.03	46.62		
Vieques		12.85	40.33		
Villalba		8.48	28.56		
Yabucoa		20.23	32.89	2.28	
Yauco	16.62	47.25	4.95		
Grand Total	484.45	1158.16	1611.54	124.49	85.00

Table 69: Percent of (Municipio) Hexagonal Area by Tornado Hazard per Municipio

Municipio	Tornado Warning Hazard Percent Area by Total (Municipio) Land Area				
	Low (< .05 warnings)	Medium Low (.05 - .1 warnings)	Medium (.1 - .2 warnings)	Medium High (.2 - .3 warnings)	High (>.3 warnings)
Adjuntas	45.35%	51.98%	2.67%	0.00%	0.00%
Aguada	0.00%	0.00%	92.60%	7.40%	0.00%
Aguadilla	0.00%	0.00%	99.61%	0.39%	0.00%
Aguas Buenas	0.00%	28.91%	71.09%	0.00%	0.00%
Aibonito	80.23%	18.78%	0.99%	0.00%	0.00%
Anasco	0.00%	3.05%	37.84%	36.49%	22.62%
Arecibo	6.86%	47.36%	45.78%	0.00%	0.00%
Arroyo	0.00%	15.72%	84.27%	0.01%	0.00%
Barceloneta	0.06%	92.94%	7.00%	0.00%	0.00%

Barranquitas	85.09%	14.91%	0.00%	0.00%	0.00%
Bayamon	0.00%	90.11%	9.89%	0.00%	0.00%
Cabo Rojo	35.11%	63.52%	1.37%	0.00%	0.00%
Caguas	0.00%	0.25%	99.75%	0.00%	0.00%
Camuy	56.16%	40.03%	3.70%	0.11%	0.00%
Canovanas	0.00%	0.00%	96.55%	3.45%	0.00%
Cantano	0.00%	0.00%	96.20%	3.80%	0.00%
Carolina	0.00%	14.50%	85.50%	0.00%	0.00%
Cayey	0.00%	0.99%	98.51%	0.49%	0.00%
Ceiba	8.81%	29.64%	61.55%	0.00%	0.00%
Ciales	6.67%	18.80%	74.53%	0.00%	0.00%
Cidra	0.09%	81.42%	18.49%	0.00%	0.00%
Coamo	71.51%	25.58%	2.91%	0.00%	0.00%
Comerio	1.48%	93.06%	5.46%	0.00%	0.00%
Corozal	16.20%	42.76%	41.04%	0.00%	0.00%
Culebra	4.89%	95.11%	0.00%	0.00%	0.00%
Dorado	0.00%	95.41%	4.59%	0.00%	0.00%
Fajardo	7.39%	33.79%	58.82%	0.00%	0.00%
Florida	0.00%	66.85%	33.15%	0.00%	0.00%
Guanica	55.70%	42.27%	2.02%	0.00%	0.00%
Guayama	0.00%	51.08%	48.83%	0.09%	0.00%
Guayanilla	79.84%	20.16%	0.00%	0.00%	0.00%
Guaynabo	0.00%	83.97%	16.03%	0.00%	0.00%
Gurabo	0.00%	0.00%	64.73%	35.27%	0.00%
Hatillo	25.48%	46.89%	27.63%	0.00%	0.00%
Hormigueros	6.37%	93.40%	0.23%	0.00%	0.00%
Humacao	18.05%	23.81%	58.13%	0.00%	0.00%
Isabela	0.00%	13.16%	86.74%	0.10%	0.00%
Jayuya	33.44%	25.71%	40.49%	0.36%	0.00%
Juana Diaz	0.19%	7.67%	91.73%	0.42%	0.00%
Juncos	0.00%	4.92%	89.53%	5.54%	0.00%
Lajas	2.10%	51.97%	45.93%	0.00%	0.00%
Lares	21.85%	47.87%	20.84%	9.44%	0.00%
Las Marias	0.00%	2.44%	30.22%	41.77%	25.57%
Las Piedras	0.00%	26.14%	73.86%	0.00%	0.00%
Loiza	0.00%	34.88%	65.12%	0.00%	0.00%
Luquillo	0.56%	39.52%	59.92%	0.00%	0.00%
Manati	0.00%	27.73%	72.27%	0.00%	0.00%
Maricao	0.00%	19.06%	80.86%	0.09%	0.00%
Maunabo	0.00%	0.00%	100.00%	0.00%	0.00%
Mayaguez	29.20%	5.18%	16.67%	32.25%	16.70%
Moca	0.00%	0.00%	81.32%	15.25%	3.43%

Morovis	9.12%	31.58%	59.30%	0.00%	0.00%
Naguabo	0.00%	0.75%	99.25%	0.00%	0.00%
Naranjito	11.97%	80.84%	7.19%	0.00%	0.00%
Orocovis	0.43%	67.46%	31.42%	0.69%	0.00%
Patillas	0.01%	0.33%	78.57%	21.09%	0.00%
Penuelas	12.87%	26.30%	60.82%	0.00%	0.00%
Ponce	0.89%	5.18%	93.38%	0.55%	0.00%
Quebradillas	0.37%	43.06%	56.27%	0.31%	0.00%
Río Grande	0.00%	0.60%	99.40%	0.00%	0.00%
Rincon	10.37%	43.77%	45.85%	0.00%	0.00%
Sabana Grande	0.00%	47.17%	52.83%	0.00%	0.00%
Salinas	0.16%	83.52%	16.32%	0.00%	0.00%
San German	40.82%	33.16%	26.02%	0.00%	0.00%
San Juan	0.00%	65.30%	34.70%	0.00%	0.00%
San Lorenzo	0.00%	36.69%	54.95%	8.35%	0.00%
San Sebastian	0.06%	2.83%	7.59%	20.15%	69.38%
Santa Isabel	0.97%	70.64%	28.40%	0.00%	0.00%
Toa Alta	0.00%	97.20%	2.80%	0.00%	0.00%
Toa Baja	0.00%	79.85%	20.15%	0.00%	0.00%
Trujillo Alto	0.00%	37.19%	52.99%	9.83%	0.00%
Utuado	67.90%	30.62%	1.48%	0.00%	0.00%
Vega Alta	0.00%	5.60%	94.40%	0.00%	0.00%
Vega Baja	0.00%	0.06%	99.94%	0.00%	0.00%
Vieques	0.00%	24.16%	75.84%	0.00%	0.00%
Villalba	0.00%	22.89%	77.11%	0.00%	0.00%
Yabucoa	0.00%	36.52%	59.37%	4.11%	0.00%
Yauco	24.15%	68.66%	7.19%	0.00%	0.00%

Table 70: Percent of (Island) Hexagonal Area by Tornado Hazard per Municipio

Municipio	Tornado Warning Hazard Percent Area by Total (Island) Land Area				
	Low (< .05 warnings)	Medium Low (.05 - .1 warnings)	Medium (.1 - .2 warnings)	Medium High (.2 - .3 warnings)	High (>.3 warnings)
Adjuntas	6.28%	3.01%	0.11%	0.00%	0.00%
Aguada	0.00%	0.00%	1.78%	1.84%	0.00%
Aguadilla	0.00%	0.00%	2.26%	0.11%	0.00%
Agua Buenas	0.00%	0.75%	1.33%	0.00%	0.00%
Aibonito	5.19%	0.51%	0.02%	0.00%	0.00%
Anasco	0.00%	0.10%	0.93%	11.60%	10.53%
Arecibo	1.80%	5.19%	3.61%	0.00%	0.00%
Arroyo	0.00%	0.20%	0.79%	0.00%	0.00%
Barceloneta	0.00%	1.51%	0.08%	0.00%	0.00%

Barranquitas	6.02%	0.44%	0.00%	0.00%	0.00%
Bayamon	0.00%	3.46%	0.27%	0.00%	0.00%
Cabo Rojo	5.30%	4.01%	0.06%	0.00%	0.00%
Caguas	0.00%	0.01%	3.66%	0.00%	0.00%
Camuy	5.38%	1.60%	0.11%	0.04%	0.00%
Canovanas	0.00%	0.00%	1.98%	0.92%	0.00%
Cantano	0.00%	0.00%	2.82%	1.44%	0.00%
Carolina	0.00%	0.06%	0.27%	0.00%	0.00%
Cayey	0.00%	0.04%	3.18%	0.21%	0.00%
Ceiba	0.55%	0.78%	1.16%	0.00%	0.00%
Ciales	0.92%	1.08%	3.09%	0.00%	0.00%
Cidra	0.01%	2.56%	0.42%	0.00%	0.00%
Coamo	11.52%	1.72%	0.14%	0.00%	0.00%
Comerio	0.09%	2.29%	0.10%	0.00%	0.00%
Corozal	1.42%	1.57%	1.08%	0.00%	0.00%
Culebra	0.13%	1.09%	0.00%	0.00%	0.00%
Dorado	0.00%	1.93%	0.07%	0.00%	0.00%
Fajardo	0.47%	0.89%	1.11%	0.00%	0.00%
Florida	0.00%	0.88%	0.31%	0.00%	0.00%
Guanica	4.49%	1.42%	0.05%	0.00%	0.00%
Guayama	0.00%	2.90%	2.00%	0.05%	0.00%
Guayanilla	7.09%	0.75%	0.00%	0.00%	0.00%
Guaynabo	0.00%	2.01%	0.28%	0.00%	0.00%
Gurabo	0.00%	0.00%	1.14%	8.02%	0.00%
Hatillo	2.20%	1.69%	0.72%	0.00%	0.00%
Hormigueros	0.15%	0.91%	0.00%	0.00%	0.00%
Humacao	1.68%	0.93%	1.63%	0.00%	0.00%
Isabela	0.00%	0.63%	2.98%	0.04%	0.00%
Jayuya	3.07%	0.99%	1.12%	0.13%	0.00%
Juana Diaz	0.02%	0.40%	3.46%	0.20%	0.00%
Juncos	0.00%	0.11%	1.48%	1.19%	0.00%
Lajas	0.27%	2.75%	1.75%	0.00%	0.00%
Lares	2.78%	2.55%	0.80%	4.67%	0.00%
Las Marias	0.00%	0.10%	0.87%	15.60%	13.99%
Las Piedras	0.00%	0.76%	1.55%	0.00%	0.00%
Loiza	0.00%	0.62%	0.83%	0.00%	0.00%
Luquillo	0.03%	0.88%	0.96%	0.00%	0.00%
Manati	0.00%	1.12%	2.10%	0.00%	0.00%
Maricao	0.00%	0.60%	1.84%	0.03%	0.00%
Maunabo	0.00%	0.00%	1.31%	0.00%	0.00%
Mayaguez	4.70%	0.35%	0.81%	20.20%	15.32%
Moca	0.00%	0.00%	2.54%	6.17%	2.03%

Morovis	0.73%	1.06%	1.43%	0.00%	0.00%
Naguabo	0.00%	0.03%	3.20%	0.00%	0.00%
Naranjito	0.69%	1.94%	0.12%	0.00%	0.00%
Orocovis	0.06%	3.71%	1.24%	0.35%	0.00%
Patillas	0.00%	0.01%	2.30%	8.00%	0.00%
Penuelas	1.19%	1.02%	1.69%	0.00%	0.00%
Ponce	0.22%	0.52%	6.78%	0.52%	0.00%
Quebradillas	0.02%	0.86%	0.81%	0.06%	0.00%
Rjo Grande	0.00%	0.01%	0.89%	0.00%	0.00%
Rincon	1.30%	2.30%	1.73%	0.00%	0.00%
Sabana Grande	0.00%	1.46%	1.17%	0.00%	0.00%
Salinas	0.02%	5.05%	0.71%	0.00%	0.00%
San German	4.59%	1.56%	0.88%	0.00%	0.00%
San Juan	0.00%	2.79%	1.07%	0.00%	0.00%
San Lorenzo	0.00%	1.69%	1.81%	3.57%	0.00%
San Sebastian	0.01%	0.17%	0.34%	11.53%	58.13%
Santa Isabel	0.07%	2.11%	0.61%	0.00%	0.00%
Toa Alta	0.00%	2.31%	0.05%	0.00%	0.00%
Toa Baja	0.00%	1.64%	0.30%	0.00%	0.00%
Trujillo Alto	0.00%	0.69%	0.70%	1.69%	0.00%
Utuado	16.13%	3.04%	0.11%	0.00%	0.00%
Vega Alta	0.00%	0.13%	1.62%	0.00%	0.00%
Vega Baja	0.00%	0.00%	2.89%	0.00%	0.00%
Vieques	0.00%	1.11%	2.50%	0.00%	0.00%
Villalba	0.00%	0.73%	1.77%	0.00%	0.00%
Yabucoa	0.00%	1.75%	2.04%	1.83%	0.00%
Yauco	3.43%	4.08%	0.31%	0.00%	0.00%

Table 71: Tornado Hazard Scores and Ranks by Municipio

Municipio	Tornado Hazard Score (Log Multiplied)		
	Total Score	Standardized Score (0-1)	Rank of Score (1-78)
San Sebastian	10,575.9905	1	1
Mayaguez	3,648.6263	0.3449	2
Las Marias	3,192.0979	0.3017	3
Anasco	2,398.9407	0.2267	4
Moca	692.6825	0.0654	5
Patillas	429.9594	0.0405	6
Gurabo	413.9245	0.039	7
Lares	248.4782	0.0234	8
San Lorenzo	206.7745	0.0194	9
Ponce	126.7889	0.0119	10

Yabucoa	124.1260	0.0116	11
Aguada	117.2069	0.011	12
Cantano	113.1789	0.0106	13
Trujillo Alto	95.2469	0.0089	14
Juncos	80.7070	0.0075	15
Canovanas	74.4881	0.0069	16
Arecibo	63.3328	0.0059	17
Juana Diaz	61.8052	0.0057	18
Cayey	57.1671	0.0053	19
Caguas	53.9661	0.005	20
Ciales	47.6588	0.0044	21
Isabela	47.4188	0.0044	21
Naguabo	47.2061	0.0043	23
Orocovis	42.9951	0.004	24
Vega Baja	42.6846	0.0039	25
Aguadilla	39.0161	0.0036	26
Vieques	39.0613	0.0036	26
Guayama	37.4511	0.0034	28
Manati	33.1364	0.003	29
Lajas	31.1218	0.0028	30
Maricao	29.5223	0.0027	31
Rincon	30.0355	0.0027	31
Villalba	27.5551	0.0025	33
Penuelas	26.9532	0.0024	34
Humacao	25.8939	0.0023	35
Jayuya	24.9660	0.0022	36
Las Piedras	24.3905	0.0022	36
Vega Alta	24.2323	0.0022	36
Morovis	23.2200	0.0021	39
Aguas Buenas	21.0339	0.0019	40
San Juan	21.1129	0.0019	40
Sabana Grande	20.1455	0.0018	42
Salinas	20.1993	0.0018	42
Corozal	19.1122	0.0017	44
Maunabo	19.3065	0.0017	44
Ceiba	18.6464	0.0016	46
Fajardo	18.1730	0.0016	46
Luquillo	15.8852	0.0014	48
Quebradillas	16.4306	0.0014	48
San German	16.2746	0.0014	48
Hatillo	13.9830	0.0012	51
Loiza	13.4336	0.0012	51

Río Grande	13.1091	0.0011	53
Santa Isabel	13.0538	0.0011	53
Yauco	12.6028	0.0011	53
Arroyo	12.0840	0.001	56
Bayamon	10.7016	0.0009	57
Cidra	11.1079	0.0009	57
Cabo Rojo	8.9676	0.0007	59
Utua	8.4211	0.0007	59
Adjuntas	7.8321	0.0006	61
Guaynabo	7.9513	0.0006	61
Toa Baja	7.5512	0.0006	61
Camuy	6.9609	0.0005	64
Coamo	6.1087	0.0005	64
Florida	6.3114	0.0005	64
Comerio	5.8458	0.0004	67
Naranjito	5.5998	0.0004	67
Toa Alta	5.1611	0.0004	67
Barceloneta	4.1016	0.0003	70
Carolina	4.1021	0.0003	70
Dorado	4.6986	0.0003	70
Guanica	3.7434	0.0002	73
Culebra	2.1129	0.0001	74
Guayanilla	1.8803	0.0001	74
Hormigueros	1.7947	0.0001	74
Aibonito	1.5841	0.0000	77
Barranquitas	1.2231	0.0000	77

Wildfire

Hazard Overview

A wildfire is any type of forest, grass, brush, or outdoor fire that is not controlled or supervised. While wildfire occurrence and extent are generally controlled by climate, occurrence and extent of wildfires is also controlled by local factors such as ignition source, topography, local weather patterns, variations in fuel characteristics (type and condition), land-use practices, and overall management practices.³¹ Across much of the Caribbean, wildfires tend to occur mainly in grasslands, croplands, or dry forest areas. Time of day, climate, and land cover have been the most significant drivers of wildfire across Puerto Rico. Irrespective of how they start or how they spread, wildfires pose significant threat to lives and livelihoods across Puerto Rico.

Data and Methods

Like several other hazards in this assessment, wildfire extent data is not readily available for Puerto Rico from a national assessment such as the Monitoring Trends in Burn Severity (MTBS) database³² or the USGS Geospatial Multi-Agency Coordination (GeoMAC), or the National Interagency Fire Center³³. For this assessment, barrio level wildfire occurrence data associated with USDA and US Forest Service Research on wildfire predictability was provided for use by UDA Caribbean Climate Hub.³⁴ The average annual number of wildfire events (2003 – 2011) for each barrio was first calculated and then spatially joined with the Puerto Rico hexagonal grid to create a representation of wildfire hazard threat across the island.

Hazard Frequency Analysis Results

Wildfire threat is higher across southern Puerto Rico than the remainder of the commonwealth (Figure 25). Three municipios (Guayama, Salinas, and Santa Isabella) have high historical wildfire frequency using the classifications scheme provided by Monmany et al. (2017).³⁵ Table 72 shows an additional 17 municipios containing medium-high wildfire hazard areas. Table 73 and Table 74 provide a breakdown of wildfire hazard area by municipio and island area respectively. Finally, Table 75 ranks each municipio by its overall wildfire hazard score.

³¹ <https://www.fs.usda.gov/treearch/pubs/54146>

³² <https://www.mtbs.gov/>

³³ <https://www.nifc.gov/>

³⁴ Data provided by Dr. William Gould – Research Ecologist and Director of the USDA Caribbean Climate Hub

³⁵ <https://www.fs.usda.gov/treearch/pubs/54146>

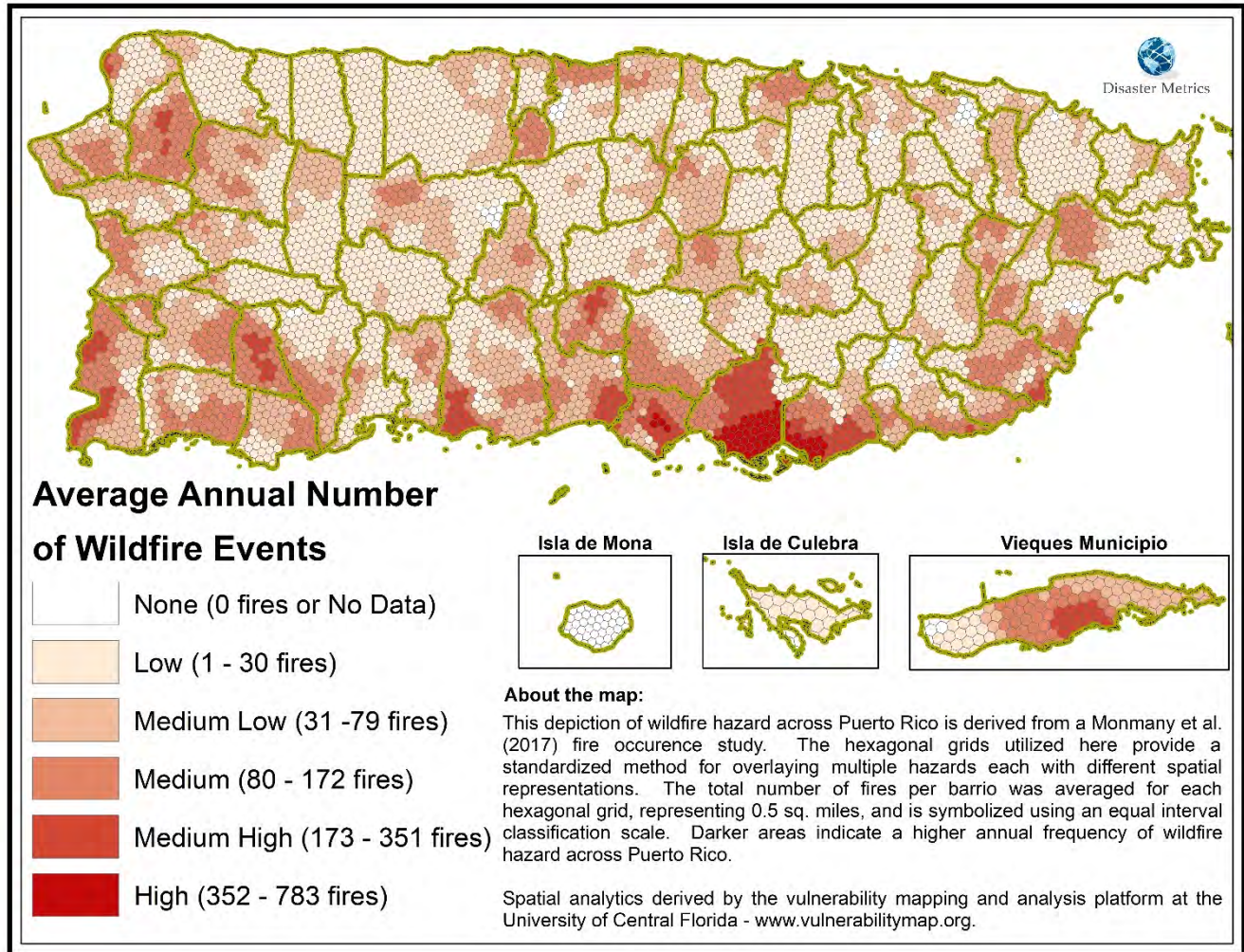


Figure 25: Wildfire Hazard Areas

Table 72: Wildfire Hazard by Municipio and Areal Extent

Municipio	HEX GRID Area by Wildfire Hazard Frequency (Sq. miles)					
	None (0 fires or No Data)	Low (1 – 30 fires)	Medium Low (31 – 79 fires)	Medium (80 – 172 fires)	Medium High (173 – 351 fires)	High (351 – 783 fires)
Adjuntas		60.84	6.25			
Aguada		5.75	15.58	9.60		
Aguadilla	0.01	24.20	7.87	2.81	1.71	
Aguas Buenas		20.67	9.42			
Aibonito		19.59	10.40	0.43	0.92	
Anasco		12.93	25.06	1.57		
Arecibo	0.00	90.57	36.40			
Arroyo		3.01	6.70	5.33		
Barceloneta		9.95	8.81			
Barranquitas		1.39	26.89	6.00		
Bayamon	0.50	42.01	2.01			

Cabo Rojo	0.00	7.02	25.07	27.24	13.79	
Caguas		49.48	9.59			
Camuy		44.30	2.07			
Canovanas	0.21	13.93	18.17	0.69		
Carolina	4.29	31.25	11.77			
Catano		0.69	4.11	0.28		
Cayey	0.50	49.65	0.67	0.83	0.30	
Ceiba	2.60	26.91	0.86			
Ciales		59.46	7.24			
Cidra		22.63	13.83			
Coamo	1.00	30.67	21.71	23.97	0.68	
Comerio		24.04	4.48			
Corozal		11.10	28.84	2.64		
Culebra	1.17	12.14				
Dorado		22.42	1.00			
Fajardo	0.00	21.16	9.35			
Florida			5.72	9.50		
Guanica	0.00	9.41	16.80	12.80		
Guayama	0.00	16.31	10.05	15.68	14.27	9.55
Guayanilla	0.14	31.20	9.84	1.81		
Guaynabo		26.83	0.93			
Gurabo		16.92	10.78	0.61		
Hatillo		41.28	0.56			
Hormigueros		0.50	7.49	3.36		
Humacao	2.78	21.70	13.41	7.21		
Isabela		41.65	13.76			
Jayuya		12.39	28.65	3.50		
Juana Diaz	0.50	3.23	33.74	14.90	8.37	
Juncos		3.90	15.52	7.20		
Lajas		13.81	24.46	23.09		
Lares		39.13	22.50			
Las Marias		21.68	22.33	2.50		
Las Piedras		9.10	18.27	6.52		
Loiza		13.82	6.71			
Luquillo		19.66	6.20			
Manati	3.20	23.44	10.53	9.65		
Maricao		28.85	6.76	1.02		
Maunabo	0.00	5.40	7.72	7.62	0.34	
Mayaguez	23.18	16.34	26.86	11.60		
Moca		3.92	11.44	31.50	3.50	
Morovis		25.98	11.76	1.18		
Naguabo		24.66	12.24	14.98		

Naranjito		24.54	3.21			
Orocovis		48.48	13.43	1.86		
Patillas	3.50	21.26	12.67	8.71	1.07	
Penuelas		17.20	20.25	7.30		
Ponce	0.50	34.40	45.53	26.98	9.58	
Quebradillas		22.92	0.22			
Rincon	0.09	0.38	11.91	2.02		
Rio Grande	0.84	51.87	8.10			
Sabana Grande		3.65	3.22	21.97	7.00	
Salinas		6.46	2.14	12.68	26.32	22.45
San German		11.60	26.86	16.04		
San Juan	2.00	30.88	16.65			
San Lorenzo		31.73	21.48			
San Sebastian		19.17	37.45	14.60		
Santa Isabel	0.05	0.50	5.29	15.58	11.16	2.00
Toa Alta		21.37	6.19			
Toa Baja		3.97	9.75	10.08		
Trujillo Alto		18.25	3.13			
Utua	4.00	70.50	33.07	7.50		
Vega Alta		15.34	12.40			
Vega Baja		22.14	21.32	3.18		
Vieques	2.41	8.76	18.92	16.33	6.76	
Villalba		1.48	15.63	15.93	4.00	
Yabucoa		11.35	20.90	20.11	3.05	
Yauco	1.00	33.17	20.29	14.36		
Grand Total	54.48	1720.25	1059.22	482.85	112.82	34.00

Table 73: Percent of (Municipio) Hexagonal Area by Wildfire Hazard per Municipio

Municipio	Wildfire Hazard Percent Area by Total (Municipio) Land Area					
	None (0 fires or No Data)	Low (1 – 30 fires)	Medium Low (31 – 79 fires)	Medium (80 – 172 fires)	Medium High (173 – 351 fires)	High (351 – 783 fires)
Adjuntas	0.00%	90.68%	9.32%	0.00%	0.00%	0.00%
Aguada	0.00%	18.60%	50.37%	31.03%	0.00%	0.00%
Aguadilla	0.03%	66.11%	21.51%	7.67%	4.68%	0.00%
Aguas Buenas	0.00%	68.70%	31.30%	0.00%	0.00%	0.00%
Aibonito	0.00%	62.51%	33.17%	1.37%	2.94%	0.00%
Anasco	0.00%	32.68%	63.36%	3.97%	0.00%	0.00%
Arecibo	0.00%	71.33%	28.67%	0.00%	0.00%	0.00%
Arroyo	0.00%	20.02%	44.53%	35.45%	0.00%	0.00%
Barceloneta	0.00%	53.02%	46.98%	0.00%	0.00%	0.00%

Barranquitas	0.00%	4.06%	78.44%	17.50%	0.00%	0.00%
Bayamon	1.12%	94.36%	4.51%	0.00%	0.00%	0.00%
Cabo Rojo	0.00%	9.60%	34.28%	37.25%	18.86%	0.00%
Caguas	0.00%	83.77%	16.23%	0.00%	0.00%	0.00%
Camuy	0.00%	95.54%	4.46%	0.00%	0.00%	0.00%
Canovanas	0.65%	42.20%	55.06%	2.09%	0.00%	0.00%
Carolina	9.06%	66.07%	24.87%	0.00%	0.00%	0.00%
Catano	0.00%	13.63%	80.92%	5.44%	0.00%	0.00%
Cayey	0.96%	95.56%	1.30%	1.60%	0.59%	0.00%
Ceiba	8.57%	88.61%	2.82%	0.00%	0.00%	0.00%
Ciales	0.00%	89.14%	10.86%	0.00%	0.00%	0.00%
Cidra	0.00%	62.08%	37.92%	0.00%	0.00%	0.00%
Coamo	1.28%	39.31%	27.82%	30.72%	0.87%	0.00%
Comerio	0.00%	84.29%	15.71%	0.00%	0.00%	0.00%
Corozal	0.00%	26.08%	67.73%	6.19%	0.00%	0.00%
Culebra	8.77%	91.23%	0.00%	0.00%	0.00%	0.00%
Dorado	0.00%	95.74%	4.26%	0.00%	0.00%	0.00%
Fajardo	0.00%	69.35%	30.65%	0.00%	0.00%	0.00%
Florida	0.00%	0.00%	37.59%	62.41%	0.00%	0.00%
Guanica	0.00%	24.11%	43.07%	32.81%	0.00%	0.00%
Guayama	0.00%	24.76%	15.26%	23.81%	21.66%	14.50%
Guayanilla	0.33%	72.57%	22.89%	4.21%	0.00%	0.00%
Guaynabo	0.00%	96.64%	3.36%	0.00%	0.00%	0.00%
Gurabo	0.00%	59.75%	38.09%	2.16%	0.00%	0.00%
Hatillo	0.00%	98.67%	1.33%	0.00%	0.00%	0.00%
Hormigueros	0.00%	4.41%	65.99%	29.61%	0.00%	0.00%
Humacao	6.17%	48.11%	29.73%	16.00%	0.00%	0.00%
Isabela	0.00%	75.17%	24.83%	0.00%	0.00%	0.00%
Jayuya	0.00%	27.81%	64.33%	7.86%	0.00%	0.00%
Juana Diaz	0.82%	5.31%	55.56%	24.53%	13.78%	0.00%
Juncos	0.00%	14.65%	58.31%	27.04%	0.00%	0.00%
Lajas	0.00%	22.51%	39.85%	37.63%	0.00%	0.00%
Lares	0.00%	63.49%	36.51%	0.00%	0.00%	0.00%
Las Marias	0.00%	46.61%	48.02%	5.38%	0.00%	0.00%
Las Piedras	0.00%	26.85%	53.90%	19.24%	0.00%	0.00%
Loiza	0.00%	67.32%	32.68%	0.00%	0.00%	0.00%
Luquillo	0.00%	76.01%	23.99%	0.00%	0.00%	0.00%
Manati	6.84%	50.06%	22.49%	20.61%	0.00%	0.00%
Maricao	0.00%	78.76%	18.47%	2.78%	0.00%	0.00%
Maunabo	0.00%	25.60%	36.63%	36.15%	1.62%	0.00%
Mayaguez	29.73%	20.95%	34.44%	14.88%	0.00%	0.00%
Moca	0.00%	7.79%	22.71%	62.55%	6.95%	0.00%

Morovis	0.00%	66.75%	30.21%	3.04%	0.00%	0.00%
Naguabo	0.00%	47.54%	23.59%	28.87%	0.00%	0.00%
Naranjito	0.00%	88.43%	11.57%	0.00%	0.00%	0.00%
Orocovis	0.00%	76.02%	21.06%	2.92%	0.00%	0.00%
Patillas	7.42%	45.04%	26.84%	18.44%	2.26%	0.00%
Penuelas	0.00%	38.43%	45.25%	16.32%	0.00%	0.00%
Ponce	0.43%	29.40%	38.92%	23.06%	8.19%	0.00%
Quebradillas	0.00%	99.05%	0.95%	0.00%	0.00%	0.00%
Rincon	0.60%	2.62%	82.78%	14.01%	0.00%	0.00%
Rio Grande	1.38%	85.29%	13.33%	0.00%	0.00%	0.00%
Sabana Grande	0.00%	10.19%	9.00%	61.28%	19.53%	0.00%
Salinas	0.00%	9.22%	3.06%	18.11%	37.57%	32.04%
San German	0.00%	21.29%	49.28%	29.43%	0.00%	0.00%
San Juan	4.04%	62.34%	33.62%	0.00%	0.00%	0.00%
San Lorenzo	0.00%	59.63%	40.37%	0.00%	0.00%	0.00%
San Sebastian	0.00%	26.91%	52.58%	20.50%	0.00%	0.00%
Santa Isabel	0.14%	1.45%	15.30%	45.06%	32.27%	5.78%
Toa Alta	0.00%	77.55%	22.45%	0.00%	0.00%	0.00%
Toa Baja	0.00%	16.69%	40.96%	42.36%	0.00%	0.00%
Trujillo Alto	0.00%	85.34%	14.66%	0.00%	0.00%	0.00%
Utuado	3.48%	61.26%	28.74%	6.52%	0.00%	0.00%
Vega Alta	0.00%	55.29%	44.71%	0.00%	0.00%	0.00%
Vega Baja	0.00%	47.47%	45.71%	6.82%	0.00%	0.00%
Vieques	4.53%	16.48%	35.57%	30.70%	12.71%	0.00%
Villalba	0.00%	3.99%	42.19%	43.01%	10.80%	0.00%
Yabucoa	0.00%	20.48%	37.72%	36.29%	5.51%	0.00%
Yauco	1.45%	48.20%	29.48%	20.87%	0.00%	0.00%

Table 74: Percent of (Island) Hexagonal Area by Wildfire Hazard per Municipio

Municipio	Wildfire Hazard Percent Area by Total (Island) Land Area					
	None (0 fires or No Data)	Low (1 – 30 fires)	Medium Low (31 – 79 fires)	Medium (80 – 172 fires)	Medium High (173 – 351 fires)	High (351 – 783 fires)
Adjuntas	0.00%	3.54%	0.59%	0.00%	0.00%	0.00%
Aguada	0.00%	0.33%	1.47%	1.99%	0.00%	0.00%
Aguadilla	0.02%	1.41%	0.74%	0.58%	1.52%	0.00%
Aguas Buenas	0.00%	1.20%	0.89%	0.00%	0.00%	0.00%
Aibonito	0.00%	1.14%	0.98%	0.09%	0.82%	0.00%
Anasco	0.00%	0.75%	2.37%	0.33%	0.00%	0.00%
Arecibo	0.00%	5.27%	3.44%	0.00%	0.00%	0.00%
Arroyo	0.00%	0.18%	0.63%	1.10%	0.00%	0.00%
Barceloneta	0.00%	0.58%	0.83%	0.00%	0.00%	0.00%

Barranquitas	0.00%	0.08%	2.54%	1.24%	0.00%	0.00%
Bayamon	0.92%	2.44%	0.19%	0.00%	0.00%	0.00%
Cabo Rojo	0.00%	0.41%	2.37%	5.64%	12.22%	0.00%
Caguas	0.00%	2.88%	0.91%	0.00%	0.00%	0.00%
Camuy	0.00%	2.58%	0.20%	0.00%	0.00%	0.00%
Canovanas	0.39%	0.81%	1.72%	0.14%	0.00%	0.00%
Carolina	7.87%	1.82%	1.11%	0.00%	0.00%	0.00%
Catano	0.00%	0.04%	0.39%	0.06%	0.00%	0.00%
Cayey	0.92%	2.89%	0.06%	0.17%	0.27%	0.00%
Ceiba	4.78%	1.56%	0.08%	0.00%	0.00%	0.00%
Ciales	0.00%	3.46%	0.68%	0.00%	0.00%	0.00%
Cidra	0.00%	1.32%	1.31%	0.00%	0.00%	0.00%
Coamo	1.84%	1.78%	2.05%	4.96%	0.60%	0.00%
Comerio	0.00%	1.40%	0.42%	0.00%	0.00%	0.00%
Corozal	0.00%	0.65%	2.72%	0.55%	0.00%	0.00%
Culebra	2.14%	0.71%	0.00%	0.00%	0.00%	0.00%
Dorado	0.00%	1.30%	0.09%	0.00%	0.00%	0.00%
Fajardo	0.00%	1.23%	0.88%	0.00%	0.00%	0.00%
Florida	0.00%	0.00%	0.54%	1.97%	0.00%	0.00%
Guanica	0.00%	0.55%	1.59%	2.65%	0.00%	0.00%
Guayama	0.01%	0.95%	0.95%	3.25%	12.65%	28.10%
Guayanilla	0.26%	1.81%	0.93%	0.38%	0.00%	0.00%
Guaynabo	0.00%	1.56%	0.09%	0.00%	0.00%	0.00%
Gurabo	0.00%	0.98%	1.02%	0.13%	0.00%	0.00%
Hatillo	0.00%	2.40%	0.05%	0.00%	0.00%	0.00%
Hormigueros	0.00%	0.03%	0.71%	0.70%	0.00%	0.00%
Humacao	5.11%	1.26%	1.27%	1.49%	0.00%	0.00%
Isabela	0.00%	2.42%	1.30%	0.00%	0.00%	0.00%
Jayuya	0.00%	0.72%	2.70%	0.72%	0.00%	0.00%
Juana Diaz	0.92%	0.19%	3.19%	3.08%	7.42%	0.00%
Juncos	0.00%	0.23%	1.47%	1.49%	0.00%	0.00%
Lajas	0.00%	0.80%	2.31%	4.78%	0.00%	0.00%
Lares	0.00%	2.27%	2.12%	0.00%	0.00%	0.00%
Las Marias	0.00%	1.26%	2.11%	0.52%	0.00%	0.00%
Las Piedras	0.00%	0.53%	1.72%	1.35%	0.00%	0.00%
Loiza	0.00%	0.80%	0.63%	0.00%	0.00%	0.00%
Luquillo	0.00%	1.14%	0.59%	0.00%	0.00%	0.00%
Manati	5.88%	1.36%	0.99%	2.00%	0.00%	0.00%
Maricao	0.00%	1.68%	0.64%	0.21%	0.00%	0.00%
Maunabo	0.00%	0.31%	0.73%	1.58%	0.30%	0.00%
Mayaguez	42.55%	0.95%	2.54%	2.40%	0.00%	0.00%
Moca	0.00%	0.23%	1.08%	6.52%	3.10%	0.00%

Morovis	0.00%	1.51%	1.11%	0.24%	0.00%	0.00%
Naguabo	0.00%	1.43%	1.16%	3.10%	0.00%	0.00%
Naranjito	0.00%	1.43%	0.30%	0.00%	0.00%	0.00%
Orocovis	0.00%	2.82%	1.27%	0.39%	0.00%	0.00%
Patillas	6.43%	1.24%	1.20%	1.80%	0.95%	0.00%
Penuelas	0.00%	1.00%	1.91%	1.51%	0.00%	0.00%
Ponce	0.92%	2.00%	4.30%	5.59%	8.49%	0.00%
Quebradillas	0.00%	1.33%	0.02%	0.00%	0.00%	0.00%
Rincon	0.16%	0.02%	1.12%	0.42%	0.00%	0.00%
Rio Grande	1.54%	3.02%	0.77%	0.00%	0.00%	0.00%
Sabana Grande	0.00%	0.21%	0.30%	4.55%	6.20%	0.00%
Salinas	0.00%	0.38%	0.20%	2.63%	23.33%	66.02%
San German	0.00%	0.67%	2.54%	3.32%	0.00%	0.00%
San Juan	3.67%	1.79%	1.57%	0.00%	0.00%	0.00%
San Lorenzo	0.00%	1.84%	2.03%	0.00%	0.00%	0.00%
San Sebastian	0.00%	1.11%	3.54%	3.02%	0.00%	0.00%
Santa Isabel	0.09%	0.03%	0.50%	3.23%	9.89%	5.88%
Toa Alta	0.00%	1.24%	0.58%	0.00%	0.00%	0.00%
Toa Baja	0.00%	0.23%	0.92%	2.09%	0.00%	0.00%
Trujillo Alto	0.00%	1.06%	0.30%	0.00%	0.00%	0.00%
Utuado	7.34%	4.10%	3.12%	1.55%	0.00%	0.00%
Vega Alta	0.00%	0.89%	1.17%	0.00%	0.00%	0.00%
Vega Baja	0.00%	1.29%	2.01%	0.66%	0.00%	0.00%
Vieques	4.42%	0.51%	1.79%	3.38%	5.99%	0.00%
Villalba	0.00%	0.09%	1.48%	3.30%	3.55%	0.00%
Yabucoa	0.00%	0.66%	1.97%	4.16%	2.70%	0.00%
Yauco	1.84%	1.93%	1.92%	2.97%	0.00%	0.00%

Table 75: Wildfire Hazard Scores and Ranks by Municipio

Municipio	Wildfire Hazard Score (Log Multiplied)		
	Total Score	Standardized Score (0-1)	Rank of Score (1-78)
Salinas	11040.8046	1	1
Guayama	4850.2696	0.4393	2
Santa Isabel	1365.4277	0.1237	3
Cabo Rojo	615.9485	0.0558	4
Ponce	459.7944	0.0416	5
Juana Diaz	372.6145	0.0337	6
Sabana Grande	336.3948	0.0305	7
Vieques	312.9490	0.0283	8
Moca	235.5172	0.0213	9
Villalba	205.9708	0.0186	10

Yabucoa	184.4270	0.0167	11
Coamo	106.8698	0.0097	12
Lajas	78.8231	0.0071	13
Aguadilla	75.9966	0.0069	14
Patillas	71.2373	0.0064	15
San German	56.9504	0.0051	16
San Sebastian	54.7805	0.0049	17
Naguabo	50.5010	0.0046	18
Yauco	50.4004	0.0046	18
Guanica	44.4271	0.004	20
Mayaguez	42.8964	0.0039	21
Aibonito	38.9091	0.0035	22
Maunabo	38.9207	0.0035	22
Aguada	33.9464	0.0031	24
Toa Baja	34.1865	0.0031	24
Manati	33.2041	0.003	26
Utua	31.8481	0.0029	27
Florida	31.4108	0.0028	28
Penuelas	27.8171	0.0025	29
Humacao	26.0839	0.0024	30
Juncos	26.2957	0.0024	30
Barranquitas	24.9666	0.0022	32
Las Piedras	24.8161	0.0022	32
Arroyo	18.4362	0.0017	34
Jayuya	17.5386	0.0016	35
Cayey	14.9117	0.0013	36
Corozal	14.8236	0.0013	36
Vega Baja	15.0282	0.0013	36
Las Marias	13.0784	0.0012	39
Hormigueros	12.3105	0.0011	40
Anasco	10.6302	0.001	41
Arecibo	8.9951	0.0008	42
Orocovis	9.3908	0.0008	42
Rincon	9.0189	0.0008	42
Guayanilla	8.2560	0.0007	45
Canovanas	6.3361	0.0006	46
Morovis	6.6211	0.0006	46
Lares	5.3747	0.0005	48
Gurabo	4.5006	0.0004	49
Maricao	5.0320	0.0004	49
San Lorenzo	5.0677	0.0004	49
Carolina	2.9292	0.0003	52

Cidra	3.2865	0.0003	52
Isabela	3.4820	0.0003	52
San Juan	3.9976	0.0003	52
Adjuntas	2.0450	0.0002	56
Aguas Buenas	2.2975	0.0002	56
Barceloneta	2.0457	0.0002	56
Caguas	2.6523	0.0002	56
Ciales	2.2474	0.0002	56
Fajardo	2.2876	0.0002	56
Rio Grande	2.3526	0.0002	56
Vega Alta	2.8935	0.0002	56
Bayamon	0.9051	0.0001	64
Camuy	0.9438	0.0001	64
Catano	1.7897	0.0001	64
Comerio	1.2499	0.0001	64
Loiza	1.6264	0.0001	64
Luquillo	1.5795	0.0001	64
Naranjito	0.9761	0.0001	64
Toa Alta	1.5949	0.0001	64
Trujillo Alto	0.8899	0.0001	64
Ceiba	0.4851	0.0000	73
Culebra	0.1340	0.0000	73
Dorado	0.4666	0.0000	73
Guaynabo	0.5013	0.0000	73
Hatillo	0.5783	0.0000	73
Quebradillas	0.3013	0.0000	73

Human Caused Hazards

Hazard Overview

Human induced hazards including chemical spills and terrorist incidents have the capacity to impact lives and livelihoods in many of the same ways natural hazards do. For the purposes of this assessment, terrorism is officially defined (by the Federal Bureau of Investigation) as "...the unlawful use of force and violence against persons or property to intimidate or coerce the government, the civilian population or any segment thereof, in the detriment of achieving political or social objectives."³⁶ The term technological hazard refers to incidents arising from human activities such as manufacturing, transportation, storage and use of hazardous materials. While terrorist events are not accidental, FEMA presumes that chemical spills and other technological events are accidental and unintentional.³⁷

Data and Methods

Terrorist incidents (1970-2018) collected from the global terrorism database and transportation incidents resulting in chemical spills (2005-2019) collected from the Pipeline and Hazardous Materials Safety Administration were summarized at the city level across Puerto Rico and annual frequencies for each were calculated. Resulting polygons representing the spatial distribution of human-caused hazard frequencies were intersected with the hexagonal grid and the maximum frequency between terrorist events and chemical spills was transposed to the hex grid as a representation of annual frequency.

Hazard Frequency Analysis Results

San Juan and Carolina stand out with the largest historical number of terrorism and transportation accidents, followed by Caguas, Aguadilla, Cataño and Guaynabo (Figure 26). San Juan and Carolina each have large amount of land (Table 76) representing greater than 60% of their land area in high human hazard zones (Table 77). This pattern continues when looking at total island-wide land area (Table 78) and places these municipios at the top in terms of overall human hazard score and ranks (Table 79).

³⁶ <https://www.fbi.gov/stats-services/publications/terrorism-2002-2005>

³⁷ <https://www.fema.gov/media-library-data/20130726-1524-20490-3869/howto7.pdf>

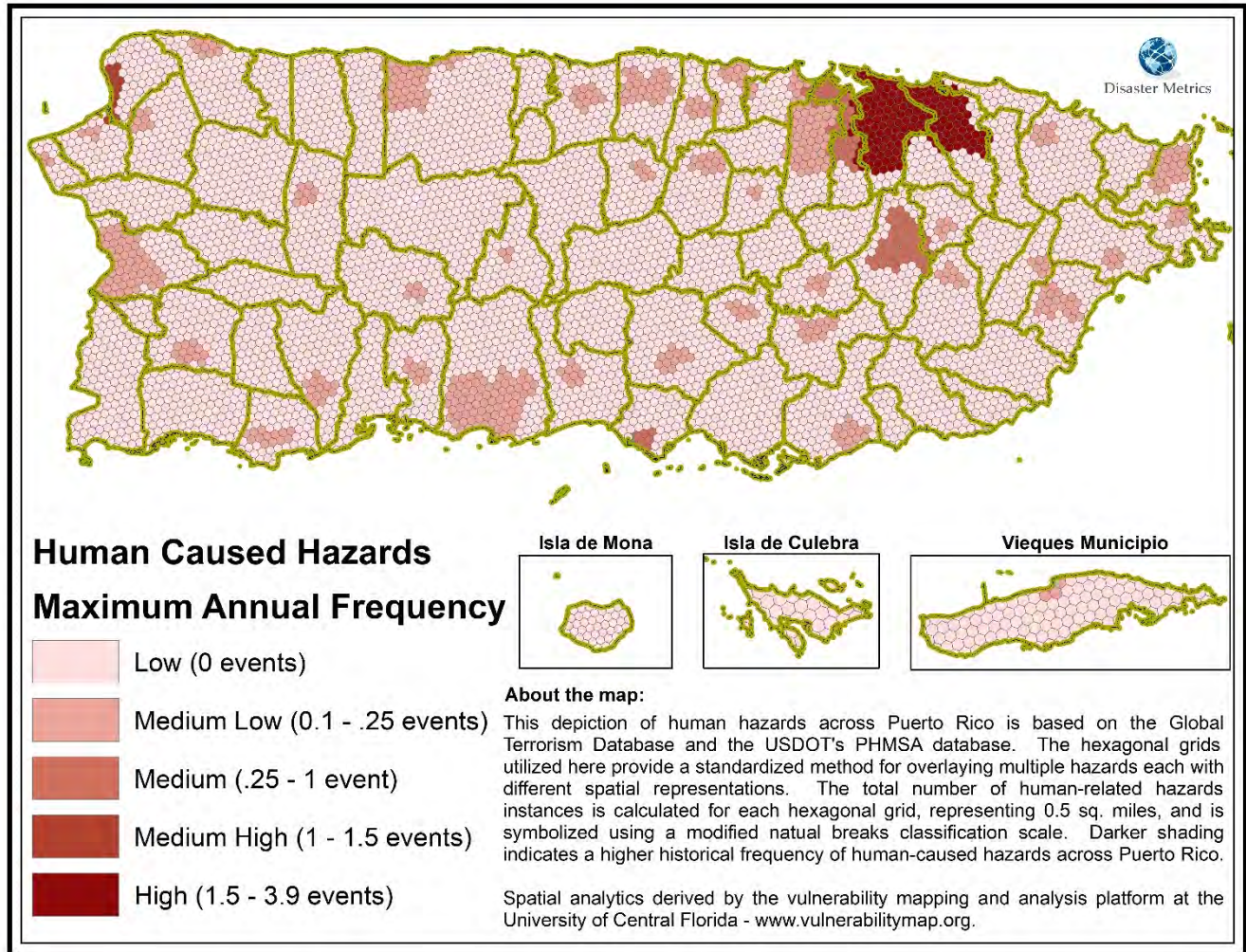


Figure 26: Human Caused Hazard Areas

Table 76: Human Caused Hazard by Municipio and Areal Extent

Municipio	HEX GRID Area by Human Caused Hazard Frequency (Sq. miles)				
	Low (0 events)	Medium Low (.1 - .25 events)	Medium (.25 – 1 events)	Medium High (1 – 1.5 events)	High (1.5 - 3.9 events)
Adjuntas	64.10	3.00			
Aguada	28.16	2.00		0.77	
Aguadilla	30.96	0.34		5.30	
Aguas Buenas	30.10				
Aibonito	27.34	4.00			
Anasco	38.53	1.03			
Arecibo	106.35	20.63			
Arroyo	15.05				
Barceloneta	18.76				
Barranquitas	34.28				
Bayamon	15.70	24.79	4.03		
Cabo Rojo	72.12	1.00			

Caguas	38.26		20.81	
Camuy	46.37			
Canovanas	32.49			0.52
Cantano	19.37			27.93
Carolina			4.99	0.10
Cayey	45.01	6.95		
Ceiba	26.44	3.93		
Ciales	66.71			
Cidra	32.91	3.55		
Coamo	72.03	6.00		
Comerio	28.52			
Corozal	36.59	5.99		
Culebra	13.31			
Dorado	16.78	6.63		
Fajardo	17.78	12.73		
Florida	15.22			
Guanica	32.52	6.49		
Guayama	58.43	7.44		
Guayanilla	42.99			
Guaynabo	12.79	0.53	9.99	4.45
Gurabo	23.67	3.00	1.64	
Hatillo	39.73	2.11		
Hormigueros	10.56	0.79		
Humacao	34.53	10.57		
Isabela	50.00	5.41		
Jayuya	43.03	1.50		
Juana Diaz	56.23	4.50		
Juncos	26.62			
Lajas	61.20	0.17		
Lares	57.64	4.00		
Las Marias	46.51			
Las Piedras	30.52	3.37		
Loiza	19.53			1.01
Luquillo	24.36	1.49		
Manati	40.55	6.27		
Maricao	36.63			
Maunabo	21.09			
Mayaguez	49.34	28.63		
Moca	46.71	3.66		
Morovis	35.93	3.00		
Naguabo	48.32	3.56		
Naranjito	26.25	1.50		

Orocovis	63.78				
Patillas	47.22				
Penuelas	40.25	4.50			
Ponce	76.14	40.84			
Quebradillas	23.14				
Río Grande	12.74	1.65			
Rincon	56.31	4.50			
Sabana Grande	35.84				
Salinas	70.06				
San German	48.17	6.34			
San Juan	5.56				43.96
San Lorenzo	48.65	4.50	0.05		
San Sebastian	71.22				
Santa Isabel	31.21		3.37		
Toa Alta	26.11	1.45			
Toa Baja	15.79	6.44	1.58		
Trujillo Alto	19.16				2.22
Utuado	115.07				
Vega Alta	22.81	4.94			
Vega Baja	32.42	14.23			
Vieques	51.53	1.66			
Villalba	37.04				
Yabucoa	55.41				
Yauco	61.82	7.00			
Grand Total	3032.33	298.59	46.44	6.06	80.20

Table 77: Percent of (Municipio) Hexagonal Area by Human Caused Hazard per Municipio

Municipio	Human Caused Hazard Percent Area by Total (Municipio) Land Area				
	Low (0 events)	Medium Low (.1 - .25 events)	Medium (.25 – 1 events)	Medium High (1 – 1.5 events)	High (1.5 - 3.9 events)
Adjuntas	95.53%	4.47%	0.00%	0.00%	0.00%
Aguada	91.06%	6.47%	0.00%	2.47%	0.00%
Aguadilla	84.59%	0.94%	0.00%	14.47%	0.00%
Aguas Buenas	100.00%	0.00%	0.00%	0.00%	0.00%
Aibonito	87.24%	12.76%	0.00%	0.00%	0.00%
Anasco	97.40%	2.60%	0.00%	0.00%	0.00%
Arecibo	83.76%	16.24%	0.00%	0.00%	0.00%
Arroyo	100.00%	0.00%	0.00%	0.00%	0.00%
Barceloneta	100.00%	0.00%	0.00%	0.00%	0.00%
Barranquitas	100.00%	0.00%	0.00%	0.00%	0.00%
Bayamon	35.27%	55.69%	9.05%	0.00%	0.00%

Cabo Rojo	98.63%	1.37%	0.00%	0.00%	0.00%
Caguas	64.78%	0.00%	35.22%	0.00%	0.00%
Camuy	100.00%	0.00%	0.00%	0.00%	0.00%
Canovanas	98.43%	0.00%	0.00%	0.00%	1.57%
Cantano	0.00%	0.00%	98.05%	0.00%	1.95%
Carolina	40.95%	0.00%	0.00%	0.00%	59.05%
Cayey	86.62%	13.38%	0.00%	0.00%	0.00%
Ceiba	87.05%	12.95%	0.00%	0.00%	0.00%
Ciales	100.00%	0.00%	0.00%	0.00%	0.00%
Cidra	90.27%	9.73%	0.00%	0.00%	0.00%
Coamo	92.31%	7.69%	0.00%	0.00%	0.00%
Comerio	100.00%	0.00%	0.00%	0.00%	0.00%
Corozal	85.93%	14.07%	0.00%	0.00%	0.00%
Culebra	100.00%	0.00%	0.00%	0.00%	0.00%
Dorado	71.67%	28.33%	0.00%	0.00%	0.00%
Fajardo	58.28%	41.72%	0.00%	0.00%	0.00%
Florida	100.00%	0.00%	0.00%	0.00%	0.00%
Guanica	83.35%	16.65%	0.00%	0.00%	0.00%
Guayama	88.70%	11.30%	0.00%	0.00%	0.00%
Guayanilla	100.00%	0.00%	0.00%	0.00%	0.00%
Guaynabo	46.08%	1.92%	35.97%	0.00%	16.04%
Gurabo	83.61%	10.60%	5.79%	0.00%	0.00%
Hatillo	94.96%	5.04%	0.00%	0.00%	0.00%
Hormigueros	93.07%	6.93%	0.00%	0.00%	0.00%
Humacao	76.56%	23.44%	0.00%	0.00%	0.00%
Isabela	90.24%	9.76%	0.00%	0.00%	0.00%
Jayuya	96.63%	3.37%	0.00%	0.00%	0.00%
Juana Diaz	92.59%	7.41%	0.00%	0.00%	0.00%
Juncos	100.00%	0.00%	0.00%	0.00%	0.00%
Lajas	99.73%	0.27%	0.00%	0.00%	0.00%
Lares	93.51%	6.49%	0.00%	0.00%	0.00%
Las Marias	100.00%	0.00%	0.00%	0.00%	0.00%
Las Piedras	90.06%	9.94%	0.00%	0.00%	0.00%
Loiza	95.09%	0.00%	0.00%	0.00%	4.91%
Luquillo	94.22%	5.78%	0.00%	0.00%	0.00%
Manati	86.61%	13.39%	0.00%	0.00%	0.00%
Maricao	100.00%	0.00%	0.00%	0.00%	0.00%
Maunabo	100.00%	0.00%	0.00%	0.00%	0.00%
Mayaguez	63.28%	36.72%	0.00%	0.00%	0.00%
Moca	92.74%	7.26%	0.00%	0.00%	0.00%
Morovis	92.29%	7.71%	0.00%	0.00%	0.00%
Naguabo	93.14%	6.86%	0.00%	0.00%	0.00%

Naranjito	94.59%	5.41%	0.00%	0.00%	0.00%
Orocovis	100.00%	0.00%	0.00%	0.00%	0.00%
Patillas	100.00%	0.00%	0.00%	0.00%	0.00%
Penuelas	89.94%	10.06%	0.00%	0.00%	0.00%
Ponce	65.09%	34.91%	0.00%	0.00%	0.00%
Quebradillas	100.00%	0.00%	0.00%	0.00%	0.00%
Rio Grande	88.51%	11.49%	0.00%	0.00%	0.00%
Rincon	92.60%	7.40%	0.00%	0.00%	0.00%
Sabana Grande	100.00%	0.00%	0.00%	0.00%	0.00%
Salinas	100.00%	0.00%	0.00%	0.00%	0.00%
San German	88.37%	11.63%	0.00%	0.00%	0.00%
San Juan	11.24%	0.00%	0.00%	0.00%	88.76%
San Lorenzo	91.44%	8.46%	0.10%	0.00%	0.00%
San Sebastian	100.00%	0.00%	0.00%	0.00%	0.00%
Santa Isabel	90.26%	0.00%	9.74%	0.00%	0.00%
Toa Alta	94.75%	5.25%	0.00%	0.00%	0.00%
Toa Baja	66.33%	27.05%	6.62%	0.00%	0.00%
Trujillo Alto	89.61%	0.00%	0.00%	0.00%	10.39%
Utuado	100.00%	0.00%	0.00%	0.00%	0.00%
Vega Alta	82.21%	17.79%	0.00%	0.00%	0.00%
Vega Baja	69.49%	30.51%	0.00%	0.00%	0.00%
Vieques	96.89%	3.11%	0.00%	0.00%	0.00%
Villalba	100.00%	0.00%	0.00%	0.00%	0.00%
Yabucoa	100.00%	0.00%	0.00%	0.00%	0.00%
Yauco	89.83%	10.17%	0.00%	0.00%	0.00%

Table 78: Percent of (Island) Hexagonal Area by Human Caused Hazard per Municipio

Municipio	Human Caused Hazard Percent Area by Total (Island) Land Area				
	Low (0 events)	Medium Low (.1 - .25 events)	Medium (.25 – 1 events)	Medium High (1 – 1.5 events)	High (1.5 - 3.9 events)
Adjuntas	1.85%	0.09%	0.00%	0.00%	0.00%
Aguada	0.81%	0.06%	0.00%	0.02%	0.00%
Aguadilla	0.89%	0.01%	0.00%	0.15%	0.00%
Aguas Buenas	0.87%	0.00%	0.00%	0.00%	0.00%
Aibonito	0.79%	0.12%	0.00%	0.00%	0.00%
Anasco	1.11%	0.03%	0.00%	0.00%	0.00%
Arecibo	3.07%	0.60%	0.00%	0.00%	0.00%
Arroyo	0.43%	0.00%	0.00%	0.00%	0.00%
Barceloneta	0.54%	0.00%	0.00%	0.00%	0.00%
Barranquitas	0.99%	0.00%	0.00%	0.00%	0.00%
Bayamon	0.45%	0.72%	0.12%	0.00%	0.00%
Cabo Rojo	2.08%	0.03%	0.00%	0.00%	0.00%

Caguas	1.10%	0.00%	0.60%	0.00%	0.00%
Camuy	1.34%	0.00%	0.00%	0.00%	0.00%
Canovanas	0.94%	0.00%	0.00%	0.00%	0.01%
Cantano	0.00%	0.00%	0.14%	0.00%	0.00%
Carolina	0.56%	0.00%	0.00%	0.00%	0.81%
Cayey	1.30%	0.20%	0.00%	0.00%	0.00%
Ceiba	0.76%	0.11%	0.00%	0.00%	0.00%
Ciales	1.93%	0.00%	0.00%	0.00%	0.00%
Cidra	0.95%	0.10%	0.00%	0.00%	0.00%
Coamo	2.08%	0.17%	0.00%	0.00%	0.00%
Comerio	0.82%	0.00%	0.00%	0.00%	0.00%
Corozal	1.06%	0.17%	0.00%	0.00%	0.00%
Culebra	0.38%	0.00%	0.00%	0.00%	0.00%
Dorado	0.48%	0.19%	0.00%	0.00%	0.00%
Fajardo	0.51%	0.37%	0.00%	0.00%	0.00%
Florida	0.44%	0.00%	0.00%	0.00%	0.00%
Guanica	0.94%	0.19%	0.00%	0.00%	0.00%
Guayama	1.69%	0.21%	0.00%	0.00%	0.00%
Guayanilla	1.24%	0.00%	0.00%	0.00%	0.00%
Guaynabo	0.37%	0.02%	0.29%	0.00%	0.13%
Gurabo	0.68%	0.09%	0.05%	0.00%	0.00%
Hatillo	1.15%	0.06%	0.00%	0.00%	0.00%
Hormigueros	0.30%	0.02%	0.00%	0.00%	0.00%
Humacao	1.00%	0.31%	0.00%	0.00%	0.00%
Isabela	1.44%	0.16%	0.00%	0.00%	0.00%
Jayuya	1.24%	0.04%	0.00%	0.00%	0.00%
Juana Diaz	1.62%	0.13%	0.00%	0.00%	0.00%
Juncos	0.77%	0.00%	0.00%	0.00%	0.00%
Lajas	1.77%	0.00%	0.00%	0.00%	0.00%
Lares	1.66%	0.12%	0.00%	0.00%	0.00%
Las Marias	1.34%	0.00%	0.00%	0.00%	0.00%
Las Piedras	0.88%	0.10%	0.00%	0.00%	0.00%
Loiza	0.56%	0.00%	0.00%	0.00%	0.03%
Luquillo	0.70%	0.04%	0.00%	0.00%	0.00%
Manati	1.17%	0.18%	0.00%	0.00%	0.00%
Maricao	1.06%	0.00%	0.00%	0.00%	0.00%
Maunabo	0.61%	0.00%	0.00%	0.00%	0.00%
Mayaguez	1.42%	0.83%	0.00%	0.00%	0.00%
Moca	1.35%	0.11%	0.00%	0.00%	0.00%
Morovis	1.04%	0.09%	0.00%	0.00%	0.00%
Naguabo	1.40%	0.10%	0.00%	0.00%	0.00%
Naranjito	0.76%	0.04%	0.00%	0.00%	0.00%

Orocovis	1.84%	0.00%	0.00%	0.00%	0.00%
Patillas	1.36%	0.00%	0.00%	0.00%	0.00%
Penuelas	1.16%	0.13%	0.00%	0.00%	0.00%
Ponce	2.20%	1.18%	0.00%	0.00%	0.00%
Quebradillas	0.67%	0.00%	0.00%	0.00%	0.00%
Rjo Grande	0.37%	0.05%	0.00%	0.00%	0.00%
Rincon	1.63%	0.13%	0.00%	0.00%	0.00%
Sabana Grande	1.03%	0.00%	0.00%	0.00%	0.00%
Salinas	2.02%	0.00%	0.00%	0.00%	0.00%
San German	1.39%	0.18%	0.00%	0.00%	0.00%
San Juan	0.16%	0.00%	0.00%	0.00%	1.27%
San Lorenzo	1.40%	0.13%	0.00%	0.00%	0.00%
San Sebastian	2.06%	0.00%	0.00%	0.00%	0.00%
Santa Isabel	0.90%	0.00%	0.10%	0.00%	0.00%
Toa Alta	0.75%	0.04%	0.00%	0.00%	0.00%
Toa Baja	0.46%	0.19%	0.05%	0.00%	0.00%
Trujillo Alto	0.55%	0.00%	0.00%	0.00%	0.06%
Utuado	3.32%	0.00%	0.00%	0.00%	0.00%
Vega Alta	0.66%	0.14%	0.00%	0.00%	0.00%
Vega Baja	0.94%	0.41%	0.00%	0.00%	0.00%
Vieques	1.49%	0.05%	0.00%	0.00%	0.00%
Villalba	1.07%	0.00%	0.00%	0.00%	0.00%
Yabucoa	1.60%	0.00%	0.00%	0.00%	0.00%
Yauco	1.78%	0.20%	0.00%	0.00%	0.00%

Table 79: Human Caused Hazard Scores and Ranks by Municipio

Municipio	Human Caused Hazard Score (Log Multiplied)		
	Total Score	Standardized Score (0-1)	Rank of Score (1-78)
San Juan	10,000.0484	1.0000	1
Carolina	6,354.3376	0.6354	2
Guaynabo	1,061.0618	0.1061	3
Aguadilla	1,000.3534	0.1000	4
Trujillo Alto	505.5319	0.0505	5
Loiza	229.5227	0.0229	6
Aguada	145.2241	0.0145	7
Canovanas	118.2374	0.0118	8
Caguas	100.3325	0.0100	9
Cantano	46.5066	0.0046	10
Bayamon	25.5670	0.0025	11
Santa Isabel	16.4612	0.0016	12
Ponce	10.6617	0.0011	13

Gurabo	8.8239	0.0009	14
Toa Baja	9.2897	0.0009	14
Mayaguez	7.4389	0.0007	16
Arecibo	5.9751	0.0006	17
Vega Baja	3.7666	0.0004	18
Fajardo	3.2714	0.0003	19
Humacao	2.8890	0.0003	19
Cayey	2.0934	0.0002	21
Coamo	2.0952	0.0002	21
Corozal	1.7852	0.0002	21
Dorado	1.7702	0.0002	21
Guanica	1.8728	0.0002	21
Guayama	2.3298	0.0002	21
Isabela	1.7582	0.0002	21
Manati	1.8874	0.0002	21
San German	1.9708	0.0002	21
San Lorenzo	1.7848	0.0002	21
Yauco	2.2513	0.0002	21
Adjuntas	1.2916	0.0001	32
Aibonito	1.2171	0.0001	32
Cabo Rojo	0.8715	0.0001	32
Ceiba	1.1928	0.0001	32
Cidra	1.1549	0.0001	32
Hatillo	0.8617	0.0001	32
Jayuya	0.7413	0.0001	32
Juana Diaz	1.5906	0.0001	32
Lares	1.4804	0.0001	32
Las Piedras	1.0904	0.0001	32
Moca	1.3012	0.0001	32
Morovis	1.0468	0.0001	32
Naguabo	1.2912	0.0001	32
Penuelas	1.4526	0.0001	32
Rincon	1.5913	0.0001	32
San Sebastian	0.6189	0.0001	32
Utua	1.0000	0.0001	32
Vega Alta	1.4067	0.0001	32
Vieques	0.8533	0.0001	32
Aguas Buenas	0.2615	0.0000	51
Anasco	0.5868	0.0000	51
Arroyo	0.1308	0.0000	51
Barceloneta	0.1630	0.0000	51
Barranquitas	0.2979	0.0000	51

Camuy	0.4030	0.0000	51
Ciales	0.5797	0.0000	51
Comerio	0.2479	0.0000	51
Culebra	0.1156	0.0000	51
Florida	0.1323	0.0000	51
Guayanilla	0.3736	0.0000	51
Hormigueros	0.2842	0.0000	51
Juncos	0.2313	0.0000	51
Lajas	0.5729	0.0000	51
Las Marias	0.4042	0.0000	51
Luquillo	0.5776	0.0000	51
Maricao	0.3183	0.0000	51
Maunabo	0.1833	0.0000	51
Naranjito	0.5954	0.0000	51
Orocovis	0.5542	0.0000	51
Patillas	0.4103	0.0000	51
Quebradillas	0.2011	0.0000	51
Río Grande	0.5154	0.0000	51
Sabana Grande	0.3115	0.0000	51
Salinas	0.6088	0.0000	51
Toa Alta	0.5811	0.0000	51
Villalba	0.3219	0.0000	51
Yabucoa	0.4815	0.0000	51

Liquefaction

Hazard Overview

Liquefaction is a phenomenon causing unconsolidated soils to lose strength and act like viscous fluid when subjected to earthquake ground shaking. Liquefaction can result subsidence of land during an earthquake event. Liquefaction frequency and intensity is based on several factors, including the geologic conditions of the area, groundwater depth, ground shaking intensity, and the magnitude of the earthquake.³⁸

Data and Methods

Universidad Metropolitana, in partnership with URS Corporation, completed an integrated hazard assessment for Puerto Rico (2002). One output of this work was an assessment of liquefaction-induced ground failure potential hazard zones across most of Puerto Rico (excluding Vieques, Isla de Culebra, and Isla de Mona). Relative liquefaction susceptibility was characterized by evaluating soil/geologic conditions and groundwater depth. Based on these characteristics, a relative liquefaction susceptibility rating (e.g., very low to very high) was assigned based on classification systems established by Youd and Perkins (1978).³⁹ Sandy soils with shallower water tables present a greater liquefaction threat than rock or rock-like materials which were considered low liquefaction hazard. These zones, originally created for each municipio, were combined and mapped using the same classification system provided in the initial assessment.

Hazard Frequency Analysis Results

Largely a coastal and river basin phenomena, liquefaction hazard zones can be found in nearly every contiguous municipio across Puerto Rico. Each municipio, with the exception of Maricao in Western Puerto Rico has at least some areas with greater than low liquefaction hazard potential (Figure 27). Table 80 displays municipio area in each liquefaction hazard zone and identifies 18 municipios containing high liquefaction hazard zones. Table 81 and Table 82 provide municipio- and island-wide area by liquefaction hazard respectively. Table 83 provides a total liquefaction hazard score, a standardized score and rank by municipio.

³⁸ <http://www.geopr.org/free-data.html>

³⁹ https://www.researchgate.net/profile/T_Youd/publication/279600523_Mapping_liquefaction-induced_ground_failure_potential/links/5733901f08aea45ee838f8f2.pdf

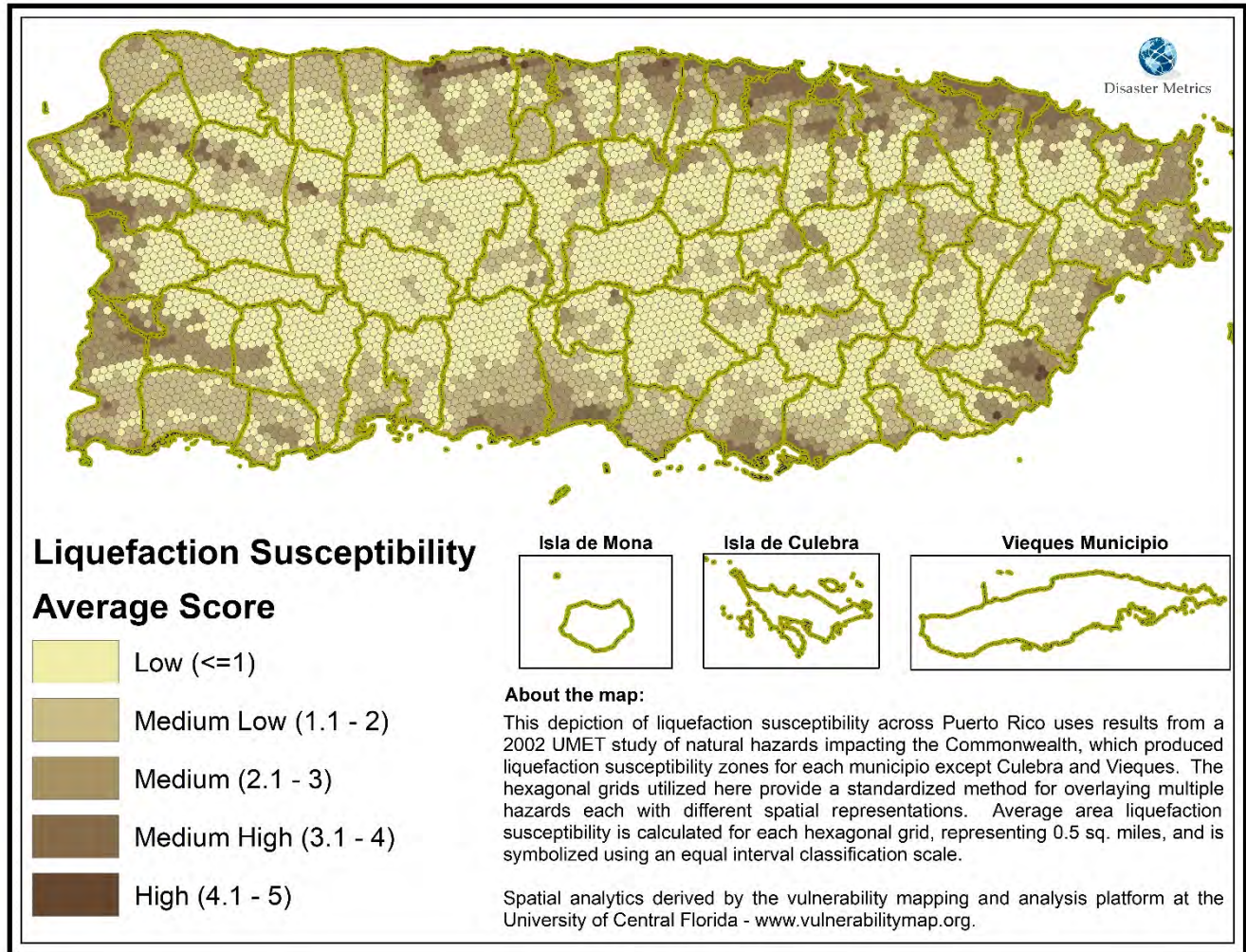


Figure 27: Liquefaction Hazard Areas

Table 80: Liquefaction Hazard by Municipio and Areal Extent

Municipio	HEX GRID Area by Liquefaction Hazard Susceptibility (Sq. miles)					
	None (No Data)	Low (Class 1)	Medium Low (Class 2)	Medium (Class 3)	Medium High (Class 4)	High (Class 5)
Adjuntas		64.60	2.50			
Aguada	0.00	17.05	3.98	6.98	1.01	1.90
Aguadilla		2.20	27.47	6.00	0.58	0.36
Aguas Buenas		25.57	1.39	3.13		
Aibonito		20.73	10.61			
Anasco		16.08	4.04	11.99	7.45	0.00
Arecibo	0.00	53.69	46.77	15.23	8.24	3.05
Arroyo		5.65	6.43	2.51	0.46	
Barceloneta	0.01	4.96	5.14	6.16	1.84	0.65
Barranquitas		25.62	8.66			
Bayamon		20.10	9.61	10.92	3.89	
Cabo Rojo	0.04	10.95	26.59	29.77	5.77	

Caguas		32.90	26.17			
Camuy		27.42	17.16	1.71	0.08	
Canovanas		22.60	2.55	6.84	1.01	
Carolina	0.04	18.59	2.94	18.15	7.60	
Catano	0.02			0.63	4.43	
Cayey		39.72	11.24	1.00		
Ceiba	0.01	9.87	9.54	10.39	0.44	0.13
Ciales		50.75	10.60	5.36		
Cidra		25.39	11.06			
Coamo		67.05	10.98			
Comerio		18.00	6.66	3.87		
Corozal		31.93	6.67	3.98		
Culebra	13.31					
Dorado		3.61	5.40	8.20	5.87	0.33
Fajardo	0.56	8.08	1.63	19.73	0.51	
Florida		1.82	13.40			
Guanica	0.01	13.56	18.62	6.32	0.50	
Guayama	0.13	37.63	18.91	3.43	5.78	
Guayanilla	0.14	20.94	19.26	2.60	0.06	
Guaynabo		13.92	6.93	6.54	0.38	
Gurabo		12.74	15.57			
Hatillo		23.19	17.40	0.77	0.48	
Hormigueros		2.48	0.91	4.74	3.21	
Humacao	0.18	10.97	26.35	4.25	3.35	
Isabela	0.00	22.26	28.83	4.09		0.22
Jayuya		32.23	9.85	2.45		
Juana Diaz	0.12	19.97	23.34	12.19	5.08	0.03
Juncos		14.68	11.93			
Lajas	0.17	10.40	48.41	2.25	0.14	
Lares		51.47	8.17	0.50	1.50	
Las Marias		42.99	3.44	0.08		
Las Piedras		23.40	10.49			
Loiza			0.56	4.33	15.30	0.35
Luquillo		14.53	1.85	9.19	0.29	
Manati	0.20	15.71	16.43	11.31	2.82	0.36
Maricao		36.63				
Maunabo		12.41	0.75	7.43		0.50
Mayaguez	22.77	31.20	3.59	13.90	6.51	
Moca		26.64	11.63	8.94	3.16	
Morovis		23.75	12.99	2.19		
Naguabo		23.17	18.87	9.54	0.29	
Naranjito		23.97	3.77			

Orocovis		60.94	2.84			
Patillas	0.00	33.59	12.06	1.41	0.11	0.04
Penuelas	0.13	31.00	11.32	2.03	0.27	
Ponce	0.70	52.30	38.61	20.27	5.10	
Quebradillas	0.00	10.27	11.40	1.46		
Rincon	0.09	5.69	4.69	3.64		0.27
Rio Grande	0.00	39.43	1.00	13.87	6.51	
Sabana Grande		23.44	5.68	6.72		
Salinas	0.39	28.66	25.74	10.47	4.79	
San German		29.00	1.13	21.93	2.44	
San Juan	0.00	20.40	8.59	14.15	6.34	0.05
San Lorenzo		41.77	11.44			
San Sebastian		40.45	21.23	5.97	3.57	
Santa Isabel	0.13	4.87	24.60	3.31	1.67	
Toa Alta		10.70	7.67	9.19		
Toa Baja	0.00	1.00	3.62	6.27	12.10	0.81
Trujillo Alto		13.51	3.52	4.35		
Utuado		100.82	14.25			
Vega Alta		8.66	9.03	8.05	2.00	
Vega Baja	0.01	13.19	18.30	8.68	5.97	0.50
Vieques	53.18					
Villalba		24.90	9.14	2.50	0.50	
Yabucoa		25.27	6.50	17.54	4.60	1.49
Yauco		54.49	13.88	0.45		
Grand Total	92.34	1860.11	894.29	451.83	154.00	11.05

Table 81: Percent of (Municipio) Hexagonal Area by Liquefaction Hazard per Municipio

Municipio	Liquefaction Hazard Susceptibility Percent Area by Total (Municipio) Land Area					
	None (No Data)	Low (Class 1)	Medium Low (Class 2)	Medium (Class 3)	Medium High (Class 4)	High (Class 5)
Adjuntas	0.00%	96.27%	3.73%	0.00%	0.00%	0.00%
Aguada	0.01%	55.14%	12.87%	22.58%	3.25%	6.15%
Aguadilla	0.00%	6.00%	75.03%	16.40%	1.59%	0.98%
Aguas Buenas	0.00%	84.97%	4.62%	10.41%	0.00%	0.00%
Aibonito	0.00%	66.16%	33.84%	0.00%	0.00%	0.00%
Anasco	0.00%	40.65%	10.21%	30.30%	18.84%	0.01%
Arecibo	0.00%	42.28%	36.83%	11.99%	6.49%	2.41%
Arroyo	0.00%	37.53%	42.72%	16.71%	3.03%	0.00%
Barceloneta	0.06%	26.44%	27.40%	32.81%	9.84%	3.45%
Barranquitas	0.00%	74.73%	25.27%	0.00%	0.00%	0.00%
Bayamon	0.00%	45.15%	21.59%	24.54%	8.73%	0.00%
Cabo Rojo	0.05%	14.98%	36.36%	40.72%	7.89%	0.00%

Caguas	0.00%	55.70%	44.30%	0.00%	0.00%	0.00%
Camuy	0.00%	59.13%	37.01%	3.69%	0.17%	0.00%
Canovanas	0.00%	68.48%	7.74%	20.71%	3.07%	0.00%
Carolina	0.08%	39.29%	6.21%	38.36%	16.06%	0.00%
Catano	0.42%	0.00%	0.00%	12.39%	87.19%	0.00%
Cayey	0.00%	76.45%	21.62%	1.92%	0.00%	0.00%
Ceiba	0.02%	32.50%	31.39%	34.21%	1.46%	0.42%
Ciales	0.00%	76.07%	15.89%	8.03%	0.00%	0.00%
Cidra	0.00%	69.66%	30.34%	0.00%	0.00%	0.00%
Coamo	0.00%	85.93%	14.07%	0.00%	0.00%	0.00%
Comerio	0.00%	63.10%	23.35%	13.55%	0.00%	0.00%
Corozal	0.00%	74.99%	15.67%	9.34%	0.00%	0.00%
Culebra	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Dorado	0.00%	15.42%	23.05%	35.03%	25.07%	1.43%
Fajardo	1.84%	26.49%	5.34%	64.67%	1.67%	0.00%
Florida	0.00%	11.95%	88.05%	0.00%	0.00%	0.00%
Guanica	0.03%	34.76%	47.72%	16.21%	1.27%	0.00%
Guayama	0.19%	57.12%	28.70%	5.20%	8.78%	0.00%
Guayanilla	0.33%	48.70%	44.79%	6.04%	0.14%	0.00%
Guaynabo	0.00%	50.14%	24.96%	23.55%	1.35%	0.00%
Gurabo	0.00%	45.00%	55.00%	0.00%	0.00%	0.00%
Hatillo	0.00%	55.43%	41.59%	1.84%	1.14%	0.00%
Hormigueros	0.00%	21.85%	8.01%	41.83%	28.31%	0.00%
Humacao	0.40%	24.32%	58.43%	9.42%	7.43%	0.00%
Isabela	0.01%	40.18%	52.03%	7.38%	0.00%	0.40%
Jayuya	0.00%	72.38%	22.12%	5.51%	0.00%	0.00%
Juana Diaz	0.19%	32.88%	38.44%	20.07%	8.36%	0.06%
Juncos	0.00%	55.16%	44.84%	0.00%	0.00%	0.00%
Lajas	0.28%	16.95%	78.89%	3.66%	0.22%	0.00%
Lares	0.00%	83.50%	13.25%	0.81%	2.43%	0.00%
Las Marias	0.00%	92.43%	7.41%	0.16%	0.00%	0.00%
Las Piedras	0.00%	69.04%	30.96%	0.00%	0.00%	0.00%
Loiza	0.00%	0.00%	2.74%	21.06%	74.49%	1.70%
Luquillo	0.00%	56.18%	7.15%	35.55%	1.12%	0.00%
Manati	0.43%	33.55%	35.08%	24.15%	6.02%	0.76%
Maricao	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%
Maunabo	0.00%	58.85%	3.54%	35.24%	0.00%	2.37%
Mayaguez	29.20%	40.01%	4.60%	17.83%	8.35%	0.00%
Moca	0.00%	52.90%	23.08%	17.75%	6.27%	0.00%
Morovis	0.00%	61.01%	33.37%	5.62%	0.00%	0.00%
Naguabo	0.00%	44.67%	36.38%	18.40%	0.56%	0.00%
Naranjito	0.00%	86.40%	13.60%	0.00%	0.00%	0.00%

Orocovis	0.00%	95.55%	4.45%	0.00%	0.00%	0.00%
Patillas	0.01%	71.14%	25.55%	2.99%	0.23%	0.09%
Penuelas	0.30%	69.27%	25.29%	4.54%	0.60%	0.00%
Ponce	0.60%	44.70%	33.01%	17.33%	4.36%	0.00%
Quebradillas	0.01%	44.40%	49.27%	6.32%	0.00%	0.00%
Rincon	0.60%	39.55%	32.62%	25.32%	0.00%	1.91%
Rio Grande	0.00%	64.84%	1.64%	22.80%	10.71%	0.00%
Sabana Grande	0.00%	65.39%	15.85%	18.76%	0.00%	0.00%
Salinas	0.56%	40.91%	36.74%	14.95%	6.84%	0.00%
San German	0.00%	53.21%	2.08%	40.24%	4.48%	0.00%
San Juan	0.00%	41.19%	17.34%	28.57%	12.80%	0.10%
San Lorenzo	0.00%	78.50%	21.50%	0.00%	0.00%	0.00%
San Sebastian	0.00%	56.79%	29.81%	8.39%	5.01%	0.00%
Santa Isabel	0.37%	14.09%	71.15%	9.57%	4.83%	0.00%
Toa Alta	0.00%	38.83%	27.82%	33.35%	0.00%	0.00%
Toa Baja	0.00%	4.20%	15.23%	26.33%	50.84%	3.40%
Trujillo Alto	0.00%	63.19%	16.48%	20.33%	0.00%	0.00%
Utuado	0.00%	87.62%	12.38%	0.00%	0.00%	0.00%
Vega Alta	0.00%	31.22%	32.57%	29.01%	7.20%	0.00%
Vega Baja	0.02%	28.28%	39.23%	18.60%	12.80%	1.07%
Vieques	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Villalba	0.00%	67.22%	24.68%	6.75%	1.35%	0.00%
Yabucoa	0.00%	45.61%	11.73%	31.66%	8.29%	2.69%
Yauco	0.00%	79.18%	20.17%	0.65%	0.00%	0.00%

Table 82: Percent of (Island) Hexagonal Area by Liquefaction Hazard per Municipio

Municipio	Liquefaction Hazard Susceptibility Percent Area by Total (Island) Land Area					
	None (No Data)	Low (Class 1)	Medium Low (Class 2)	Medium (Class 3)	Medium High (Class 4)	High (Class 5)
Adjuntas	0.00%	3.47%	0.28%	0.00%	0.00%	0.00%
Aguada	0.00%	0.92%	0.45%	1.55%	0.65%	17.22%
Aguadilla	0.00%	0.12%	3.07%	1.33%	0.38%	3.24%
Aguas Buenas	0.00%	1.37%	0.16%	0.69%	0.00%	0.00%
Aibonito	0.00%	1.11%	1.19%	0.00%	0.00%	0.00%
Anasco	0.00%	0.86%	0.45%	2.65%	4.84%	0.03%
Arecibo	0.00%	2.89%	5.23%	3.37%	5.35%	27.64%
Arroyo	0.00%	0.30%	0.72%	0.56%	0.30%	0.00%
Barceloneta	0.01%	0.27%	0.57%	1.36%	1.20%	5.85%
Barranquitas	0.00%	1.38%	0.97%	0.00%	0.00%	0.00%
Bayamon	0.00%	1.08%	1.07%	2.42%	2.52%	0.00%
Cabo Rojo	0.04%	0.59%	2.97%	6.59%	3.75%	0.00%
Caguas	0.00%	1.77%	2.93%	0.00%	0.00%	0.00%

Camuy	0.00%	1.47%	1.92%	0.38%	0.05%	0.00%
Canovanas	0.00%	1.22%	0.29%	1.51%	0.66%	0.00%
Carolina	0.04%	1.00%	0.33%	4.02%	4.93%	0.00%
Catano	0.02%	0.00%	0.00%	0.14%	2.88%	0.00%
Cayey	0.00%	2.14%	1.26%	0.22%	0.00%	0.00%
Ceiba	0.01%	0.53%	1.07%	2.30%	0.29%	1.14%
Ciales	0.00%	2.73%	1.19%	1.19%	0.00%	0.00%
Cidra	0.00%	1.37%	1.24%	0.00%	0.00%	0.00%
Coamo	0.00%	3.60%	1.23%	0.00%	0.00%	0.00%
Comerio	0.00%	0.97%	0.74%	0.86%	0.00%	0.00%
Corozal	0.00%	1.72%	0.75%	0.88%	0.00%	0.00%
Culebra	14.41%	0.00%	0.00%	0.00%	0.00%	0.00%
Dorado	0.00%	0.19%	0.60%	1.82%	3.81%	3.03%
Fajardo	0.61%	0.43%	0.18%	4.37%	0.33%	0.00%
Florida	0.00%	0.10%	1.50%	0.00%	0.00%	0.00%
Guanica	0.01%	0.73%	2.08%	1.40%	0.32%	0.00%
Guayama	0.14%	2.02%	2.11%	0.76%	3.75%	0.00%
Guayanilla	0.15%	1.13%	2.15%	0.57%	0.04%	0.00%
Guaynabo	0.00%	0.75%	0.77%	1.45%	0.24%	0.00%
Gurabo	0.00%	0.68%	1.74%	0.00%	0.00%	0.00%
Hatillo	0.00%	1.25%	1.95%	0.17%	0.31%	0.00%
Hormigueros	0.00%	0.13%	0.10%	1.05%	2.09%	0.00%
Humacao	0.20%	0.59%	2.95%	0.94%	2.18%	0.00%
Isabela	0.00%	1.20%	3.22%	0.91%	0.00%	2.00%
Jayuya	0.00%	1.73%	1.10%	0.54%	0.00%	0.00%
Juana Diaz	0.13%	1.07%	2.61%	2.70%	3.30%	0.30%
Juncos	0.00%	0.79%	1.33%	0.00%	0.00%	0.00%
Lajas	0.18%	0.56%	5.41%	0.50%	0.09%	0.00%
Lares	0.00%	2.77%	0.91%	0.11%	0.97%	0.00%
Las Marias	0.00%	2.31%	0.39%	0.02%	0.00%	0.00%
Las Piedras	0.00%	1.26%	1.17%	0.00%	0.00%	0.00%
Loiza	0.00%	0.00%	0.06%	0.96%	9.93%	3.16%
Luquillo	0.00%	0.78%	0.21%	2.03%	0.19%	0.00%
Manati	0.22%	0.84%	1.84%	2.50%	1.83%	3.21%
Maricao	0.00%	1.97%	0.00%	0.00%	0.00%	0.00%
Maunabo	0.00%	0.67%	0.08%	1.64%	0.00%	4.52%
Mayaguez	24.66%	1.68%	0.40%	3.08%	4.23%	0.00%
Moca	0.00%	1.43%	1.30%	1.98%	2.05%	0.00%
Morovis	0.00%	1.28%	1.45%	0.48%	0.00%	0.00%
Naguabo	0.00%	1.25%	2.11%	2.11%	0.19%	0.00%
Naranjito	0.00%	1.29%	0.42%	0.00%	0.00%	0.00%
Orocovis	0.00%	3.28%	0.32%	0.00%	0.00%	0.00%

Patillas	0.00%	1.81%	1.35%	0.31%	0.07%	0.38%
Penuelas	0.14%	1.67%	1.27%	0.45%	0.18%	0.00%
Ponce	0.76%	2.81%	4.32%	4.49%	3.31%	0.00%
Quebradillas	0.00%	0.55%	1.27%	0.32%	0.00%	0.00%
Rincon	0.09%	0.31%	0.52%	0.81%	0.00%	2.49%
Rio Grande	0.00%	2.12%	0.11%	3.07%	4.23%	0.00%
Sabana Grande	0.00%	1.26%	0.64%	1.49%	0.00%	0.00%
Salinas	0.42%	1.54%	2.88%	2.32%	3.11%	0.00%
San German	0.00%	1.56%	0.13%	4.85%	1.58%	0.00%
San Juan	0.00%	1.10%	0.96%	3.13%	4.12%	0.45%
San Lorenzo	0.00%	2.25%	1.28%	0.00%	0.00%	0.00%
San Sebastian	0.00%	2.17%	2.37%	1.32%	2.32%	0.00%
Santa Isabel	0.14%	0.26%	2.75%	0.73%	1.08%	0.00%
Toa Alta	0.00%	0.58%	0.86%	2.03%	0.00%	0.00%
Toa Baja	0.00%	0.05%	0.41%	1.39%	7.86%	7.33%
Trujillo Alto	0.00%	0.73%	0.39%	0.96%	0.00%	0.00%
Utuado	0.00%	5.42%	1.59%	0.00%	0.00%	0.00%
Vega Alta	0.00%	0.47%	1.01%	1.78%	1.30%	0.00%
Vega Baja	0.01%	0.71%	2.05%	1.92%	3.88%	4.52%
Vieques	57.59%	0.00%	0.00%	0.00%	0.00%	0.00%
Villalba	0.00%	1.34%	1.02%	0.55%	0.32%	0.00%
Yabucoa	0.00%	1.36%	0.73%	3.88%	2.98%	13.50%
Yauco	0.00%	2.93%	1.55%	0.10%	0.00%	0.00%

Table 83: Liquefaction Hazard Scores and Ranks by Municipio

Municipio	Liquefaction Hazard Susceptibility Score (Log Multiplied)		
	Total Score	Standardized Score (0-1)	Rank of Score (1-78)
San Juan	10,000.0484	1.0000	1
Carolina	6,354.3376	0.6354	2
Guaynabo	1,061.0618	0.1061	3
Aguadilla	1,000.3534	0.1000	4
Trujillo Alto	505.5319	0.0505	5
Loiza	229.5227	0.0229	6
Aguada	145.2241	0.0145	7
Canovanas	118.2374	0.0118	8
Caguas	100.3325	0.0100	9
Cantano	46.5066	0.0046	10
Bayamon	25.5670	0.0025	11
Santa Isabel	16.4612	0.0016	12
Ponce	10.6617	0.0011	13

Gurabo	8.8239	0.0009	14
Arecibo	10600.2290	1.0000	1
Aguada	6319.3482	0.5962	2
Yabucoa	5246.1390	0.4949	3
Toa Baja	3463.8499	0.3268	4
Barceloneta	2259.5702	0.2132	5
Loiza	2157.0581	0.2035	6
Vega Baja	2060.0229	0.1943	7
Maunabo	1661.9379	0.1568	8
Dorado	1507.9439	0.1423	9
Manati	1388.1414	0.1310	10
Aguadilla	1236.0180	0.1166	11
Rincon	912.9101	0.0861	12
Isabela	743.8760	0.0702	13
San Juan	626.1003	0.0591	14
Carolina	558.5183	0.0527	15
Anasco	539.9570	0.0509	16
Juana Diaz	487.4644	0.0460	17
Cabo Rojo	482.8511	0.0456	18
Ceiba	478.5784	0.0451	19
Mayaguez	473.5342	0.0447	20
Rio Grande	473.0351	0.0446	21
Ponce	410.1782	0.0387	22
Guayama	393.7207	0.0371	23
Salinas	354.1422	0.0334	24
Bayamon	292.8483	0.0276	25
Catano	291.9054	0.0275	26
San Sebastian	258.2230	0.0244	27
Moca	239.0914	0.0226	28
Humacao	238.8467	0.0225	29
San German	233.7365	0.0221	30
Hormigueros	226.0768	0.0213	31
Vega Alta	159.5495	0.0151	32
Patillas	150.3974	0.0142	33
Santa Isabel	125.3396	0.0118	34
Lares	101.9350	0.0096	35
Fajardo	100.0624	0.0094	36
Canovanas	89.9216	0.0085	37
Guanica	57.7384	0.0054	38
Naguabo	55.2757	0.0052	39
Luquillo	50.3899	0.0048	40
Guaynabo	48.1174	0.0045	41

Villalba	43.2184	0.0041	42
Arroyo	39.6616	0.0037	43
Hatillo	37.5852	0.0035	44
Toa Alta	32.5591	0.0031	45
Penuelas	27.1494	0.0026	46
Lajas	26.5149	0.0025	47
Sabana Grande	23.9911	0.0023	48
Ciales	20.6870	0.0020	49
Guayanilla	16.7617	0.0016	50
Trujillo Alto	15.4608	0.0015	51
Camuy	14.8311	0.0014	52
Comerio	14.5382	0.0014	52
Corozal	15.0579	0.0014	52
Aguas Buenas	11.0653	0.0010	55
Jayuya	10.5912	0.0010	55
Morovis	10.2715	0.0010	55
Quebradillas	7.3716	0.0007	58
Cayey	6.0740	0.0006	59
Caguas	5.7316	0.0005	60
Yauco	4.9190	0.0005	60
Utuado	3.9429	0.0004	62
Coamo	2.9327	0.0003	63
Florida	2.7865	0.0003	63

Lightning

Hazard Overview

All thunderstorms produce lightning, a spark of static electricity and results from the buildup of electrical energy between positively and negatively charged areas. Whenever thunder is audible, there is the risk of a lightning strike. The only safe place during a thunderstorm is inside. Lightning has also occurred in volcanic eruptions, intense forest fires, surface nuclear detonations, heavy snowstorms, and in large hurricanes. There are four types of lightning: cloud to ground, intra-cloud, cloud-to-cloud, and cloud to air. The term “heat lightning” is a misnomer and is not related to high temperatures. Heat lightning is lightning that is simply too far away for the thunder to be audible. Cloud-to-ground lightning is responsible for most fatalities, injuries, and property damage.

Data and Methods

The lightning data (2010-2019), obtained from the World Wide Lightning Location Network⁴⁰ provide locations in latitude and longitude (decimal degree) of cloud-to-ground lightning strikes. These strike locations were plotted as points, overlaid by the .5-mile hex grid and a count of strikes was generated for each hex grid. Annual lightning frequency, calculated as the number of lightning points that are intercepted with each hexagon divided by the total number of years in record, provides a spatial representation of lightning hazard across Puerto Rico.

Hazard Frequency Analysis Results

Although lightning can occur anywhere in Puerto Rico, western portions of the main island have a higher lightning strike frequency than other areas (Figure 28). Table 84 provides an overview of land area in each municipio by lightning hazard frequency zones. Table 85 and Table 86 summarize percent land area by municipio and compared to total island-wide area respectively. Table 87 shows the total lightning hazard score, standardized score, rank for each municipio.

⁴⁰ <http://wwlln.net/>

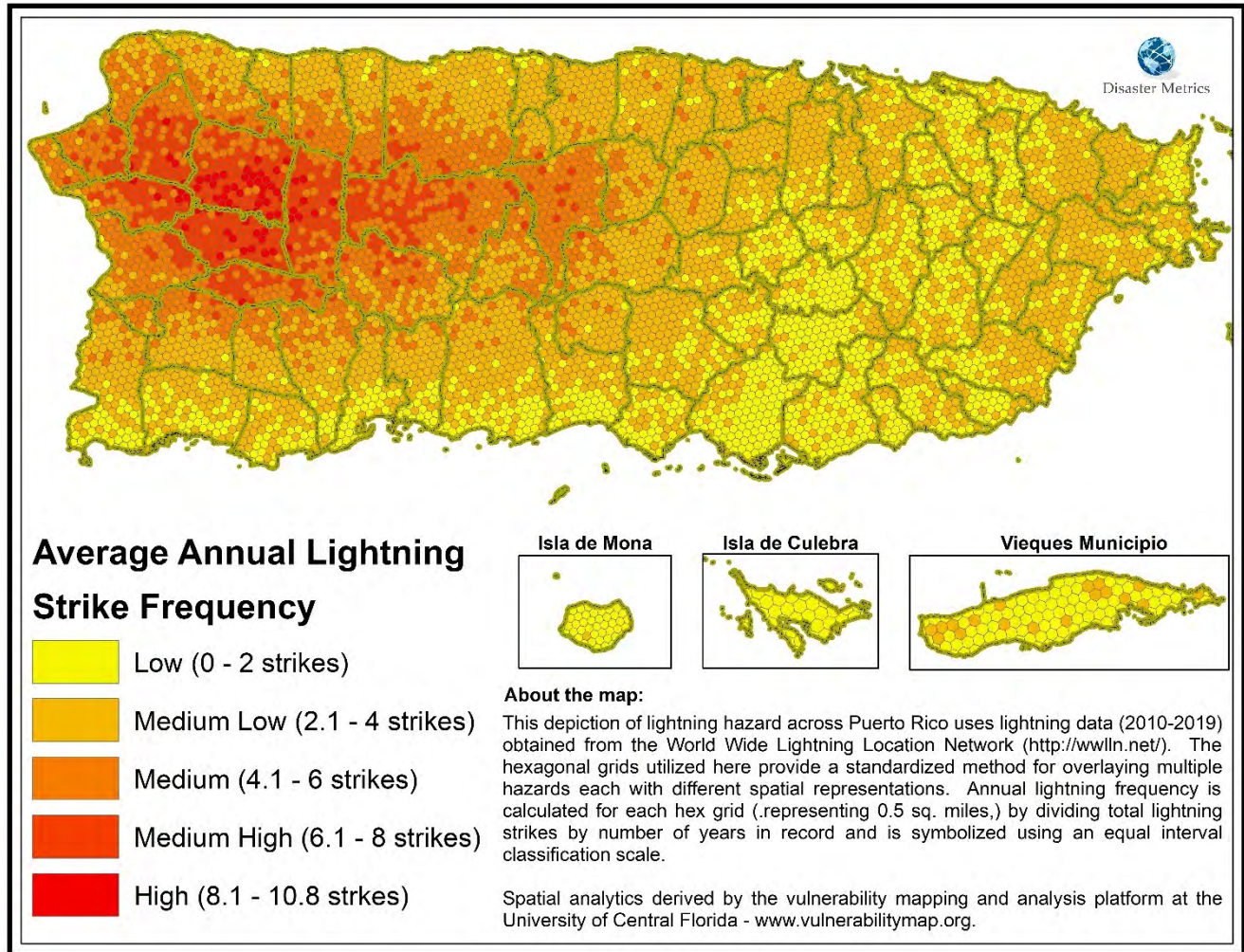


Figure 28: Lightning Hazard Areas

Table 84: Lightning Hazard by Municipio and Areal Extent

Municipio	HEX GRID Area by Annual Lightning Hazard Frequency (Sq. miles)				
	Low (0 – 2 strikes)	Medium Low (2.1 – 4 strikes)	Medium (4.1 – 6 strikes)	Medium High (6.1 – 8 strikes)	High (8.1 – 10 strikes)
Adjuntas	0.10	21.57	37.53	7.90	
Aguada	0.56	1.69	19.36	9.24	0.07
Aguadilla	1.17	14.34	20.33	0.77	
Aguas Buenas	14.21	15.88			
Aibonito	15.89	15.44			
Anasco	0.21	2.14	14.05	19.98	3.18
Arecibo	5.21	65.53	50.42	5.81	
Arroyo	11.18	3.87			
Barceloneta	2.40	16.02	0.34		
Barranquitas	7.15	27.13			
Bayamon	9.84	34.23	0.45		

Cabo Rojo	24.12	41.76	7.24		
Caguas	28.16	30.90			
Camuy	1.45	23.36	20.08	1.49	
Canovanas	19.05	13.95			
Cantano	29.55	17.75			
Carolina	1.34	3.75			
Cayey	40.95	11.01			
Ceiba	12.60	17.37	0.40		
Ciales		7.55	55.15	4.00	
Cidra	29.04	7.42			
Coamo	18.43	59.60			
Comerio	17.94	10.58			
Corozal	0.29	37.79	4.50		
Culebra	13.31				
Dorado	2.29	20.13	1.00		
Fajardo	16.96	13.55			
Florida		9.77	4.95	0.50	
Guanica	17.07	21.94			
Guayama	52.34	13.52			
Guayanilla	17.51	23.17	2.31		
Guaynabo	4.52	23.25			
Gurabo	15.56	12.75			
Hatillo	2.82	21.12	14.68	3.22	
Hormigueros		4.13	7.22		
Humacao	13.71	31.40			
Isabela	3.42	28.27	20.79	2.92	
Jayuya		20.28	23.42	0.84	
Juana Diaz	23.93	34.73	2.07		
Juncos	13.49	13.13			
Lajas	23.62	37.58	0.16		
Lares		0.92	18.73	37.39	4.59
Las Marias			3.24	34.84	8.43
Las Piedras	7.84	26.05			
Loiza	15.18	5.35			
Luquillo	3.59	22.27			
Manati	1.57	41.61	3.65		
Maricao		0.03	18.32	17.65	0.63
Maunabo	14.53	6.56			
Mayaguez	23.39	9.87	35.98	8.74	
Moca		1.36	21.12	25.44	2.45
Morovis		26.48	12.45		
Naguabo	11.14	40.64	0.10		

Naranjito	6.49	21.26			
Orocovis	0.50	47.35	15.43	0.50	
Patillas	24.68	22.53			
Penuelas	11.02	29.18	4.56		
Ponce	31.58	77.16	8.25		
Quebradillas	1.78	14.07	6.42	0.87	
Rio Grande	0.42	4.47	8.47	1.04	
Rincon	16.55	43.76	0.50		
Sabana Grande	1.42	24.11	9.98	0.33	0.00
Salinas	55.49	14.57			
San German	0.89	29.92	21.41	2.29	
San Juan	15.52	34.01			
San Lorenzo	28.14	25.07			
San Sebastian		0.26	15.80	37.02	18.14
Santa Isabel	21.89	12.69			
Toa Alta	1.16	25.19	1.21		
Toa Baja	2.47	20.49	0.84		
Trujillo Alto	11.42	9.96			
Utua		10.11	66.70	38.26	
Vega Alta	1.89	24.35	1.50		
Vega Baja	5.92	39.23	1.50		
Vieques	44.33	8.86			
Villalba	1.00	32.17	3.87		
Yabucoa	22.03	33.38			
Yauco	8.22	37.87	22.26	0.47	
Grand Total	903.44	1652.48	608.71	261.50	37.50

Table 85: Percent of (Municipio) Hexagonal Area by Lightning Hazard per Municipio

Municipio	Annual Lightning Hazard Frequency Percent Area by Total (Municipio) Land Area				
	Low (0 – 2 strikes)	Medium Low (2.1 – 4 strikes)	Medium (4.1 – 6 strikes)	Medium High (6.1 – 8 strikes)	High (8.1 – 10 strikes)
Adjuntas	0.15%	32.15%	55.93%	11.77%	0.00%
Aguada	1.81%	5.48%	62.60%	29.89%	0.23%
Aguadilla	3.20%	39.19%	55.52%	2.09%	0.00%
Aguas Buenas	47.22%	52.78%	0.00%	0.00%	0.00%
Aibonito	50.72%	49.28%	0.00%	0.00%	0.00%
Anasco	0.52%	5.41%	35.52%	50.51%	8.04%
Arecibo	4.11%	51.61%	39.71%	4.57%	0.00%
Arroyo	74.31%	25.69%	0.00%	0.00%	0.00%
Barceloneta	12.78%	85.39%	1.83%	0.00%	0.00%

Barranquitas	20.87%	79.13%	0.00%	0.00%	0.00%
Bayamon	22.10%	76.89%	1.01%	0.00%	0.00%
Cabo Rojo	32.99%	57.11%	9.90%	0.00%	0.00%
Caguas	47.68%	52.32%	0.00%	0.00%	0.00%
Camuy	3.12%	50.37%	43.29%	3.21%	0.00%
Canovanas	57.73%	42.27%	0.00%	0.00%	0.00%
Carolina	62.47%	37.53%	0.00%	0.00%	0.00%
Catano	26.34%	73.66%	0.00%	0.00%	0.00%
Cayey	78.81%	21.19%	0.00%	0.00%	0.00%
Ceiba	41.50%	57.19%	1.31%	0.00%	0.00%
Ciales	0.00%	11.32%	82.68%	6.00%	0.00%
Cidra	79.66%	20.34%	0.00%	0.00%	0.00%
Coamo	23.61%	76.39%	0.00%	0.00%	0.00%
Comerio	62.90%	37.10%	0.00%	0.00%	0.00%
Corozal	0.69%	88.75%	10.57%	0.00%	0.00%
Culebra	100.00%	0.00%	0.00%	0.00%	0.00%
Dorado	9.77%	85.96%	4.27%	0.00%	0.00%
Fajardo	55.60%	44.40%	0.00%	0.00%	0.00%
Florida	0.00%	64.18%	32.53%	3.28%	0.00%
Guanica	43.76%	56.24%	0.00%	0.00%	0.00%
Guayama	79.47%	20.53%	0.00%	0.00%	0.00%
Guayanilla	40.72%	53.90%	5.38%	0.00%	0.00%
Guaynabo	16.26%	83.74%	0.00%	0.00%	0.00%
Gurabo	54.96%	45.04%	0.00%	0.00%	0.00%
Hatillo	6.74%	50.48%	35.08%	7.69%	0.00%
Hormigueros	0.00%	36.36%	63.64%	0.00%	0.00%
Humacao	30.39%	69.61%	0.00%	0.00%	0.00%
Isabela	6.18%	51.02%	37.53%	5.28%	0.00%
Jayuya	0.00%	45.53%	52.58%	1.90%	0.00%
Juana Diaz	39.40%	57.18%	3.42%	0.00%	0.00%
Juncos	50.67%	49.33%	0.00%	0.00%	0.00%
Lajas	38.50%	61.24%	0.26%	0.00%	0.00%
Lares	0.00%	1.49%	30.39%	60.66%	7.45%
Las Marias	0.00%	0.00%	6.96%	74.91%	18.13%
Las Piedras	23.13%	76.87%	0.00%	0.00%	0.00%
Loiza	73.94%	26.06%	0.00%	0.00%	0.00%
Luquillo	13.89%	86.11%	0.00%	0.00%	0.00%
Manati	3.35%	88.86%	7.79%	0.00%	0.00%
Maricao	0.00%	0.07%	50.01%	48.19%	1.73%
Maunabo	68.89%	31.11%	0.00%	0.00%	0.00%
Mayaguez	29.99%	12.65%	46.15%	11.20%	0.00%
Moca	0.00%	2.70%	41.93%	50.51%	4.86%

Morovis	0.00%	68.02%	31.98%	0.00%	0.00%
Naguabo	21.47%	78.33%	0.20%	0.00%	0.00%
Naranjito	23.38%	76.62%	0.00%	0.00%	0.00%
Orocovis	0.78%	74.24%	24.19%	0.78%	0.00%
Patillas	52.28%	47.72%	0.00%	0.00%	0.00%
Penuelas	24.61%	65.21%	10.18%	0.00%	0.00%
Ponce	26.99%	65.96%	7.05%	0.00%	0.00%
Quebradillas	7.69%	60.80%	27.77%	3.74%	0.00%
Rincon	2.90%	31.07%	58.83%	7.20%	0.00%
Rio Grande	27.22%	71.96%	0.82%	0.00%	0.00%
Sabana Grande	3.97%	67.25%	27.86%	0.92%	0.00%
Salinas	79.20%	20.80%	0.00%	0.00%	0.00%
San German	1.64%	54.89%	39.28%	4.19%	0.00%
San Juan	31.33%	68.67%	0.00%	0.00%	0.00%
San Lorenzo	52.88%	47.12%	0.00%	0.00%	0.00%
San Sebastian	0.00%	0.36%	22.18%	51.98%	25.47%
Santa Isabel	63.30%	36.70%	0.00%	0.00%	0.00%
Toa Alta	4.20%	91.41%	4.39%	0.00%	0.00%
Toa Baja	10.39%	86.07%	3.54%	0.00%	0.00%
Trujillo Alto	53.41%	46.59%	0.00%	0.00%	0.00%
Utuado	0.00%	8.79%	57.96%	33.25%	0.00%
Vega Alta	6.82%	87.77%	5.41%	0.00%	0.00%
Vega Baja	12.68%	84.10%	3.22%	0.00%	0.00%
Vieques	83.35%	16.65%	0.00%	0.00%	0.00%
Villalba	2.70%	86.86%	10.44%	0.00%	0.00%
Yabucoa	39.76%	60.24%	0.00%	0.00%	0.00%
Yauco	11.95%	55.02%	32.34%	0.69%	0.00%

Table 86: Percent of (Island) Hexagonal Area by Lightning Hazard per Municipio

Municipio	Annual Lightning Hazard Frequency Percent Area by Total (Island) Land Area				
	Low (0 – 2 strikes)	Medium Low (2.1 – 4 strikes)	Medium (4.1 – 6 strikes)	Medium High (6.1 – 8 strikes)	High (8.1 – 10 strikes)
Adjuntas	0.01%	1.31%	6.16%	3.02%	0.00%
Aguada	0.06%	0.10%	3.18%	3.53%	0.19%
Aguadilla	0.13%	0.87%	3.34%	0.29%	0.00%
Aguas Buenas	1.57%	0.96%	0.00%	0.00%	0.00%
Aibonito	1.76%	0.93%	0.00%	0.00%	0.00%
Anasco	0.02%	0.13%	2.31%	7.64%	8.48%
Arecibo	0.58%	3.97%	8.28%	2.22%	0.00%
Arroyo	1.24%	0.23%	0.00%	0.00%	0.00%
Barceloneta	0.27%	0.97%	0.06%	0.00%	0.00%

Barranquitas	0.79%	1.64%	0.00%	0.00%	0.00%
Bayamon	1.09%	2.07%	0.07%	0.00%	0.00%
Cabo Rojo	2.67%	2.53%	1.19%	0.00%	0.00%
Caguas	3.12%	1.87%	0.00%	0.00%	0.00%
Camuy	0.16%	1.41%	3.30%	0.57%	0.00%
Canovanas	2.11%	0.84%	0.00%	0.00%	0.00%
Carolina	3.27%	1.07%	0.00%	0.00%	0.00%
Catano	0.15%	0.23%	0.00%	0.00%	0.00%
Cayey	4.53%	0.67%	0.00%	0.00%	0.00%
Ceiba	1.40%	1.05%	0.07%	0.00%	0.00%
Ciales	0.00%	0.46%	9.06%	1.53%	0.00%
Cidra	3.21%	0.45%	0.00%	0.00%	0.00%
Coamo	2.04%	3.61%	0.00%	0.00%	0.00%
Comerio	1.99%	0.64%	0.00%	0.00%	0.00%
Corozal	0.03%	2.29%	0.74%	0.00%	0.00%
Culebra	1.47%	0.00%	0.00%	0.00%	0.00%
Dorado	0.25%	1.22%	0.16%	0.00%	0.00%
Fajardo	1.88%	0.82%	0.00%	0.00%	0.00%
Florida	0.00%	0.59%	0.81%	0.19%	0.00%
Guanica	1.89%	1.33%	0.00%	0.00%	0.00%
Guayama	5.79%	0.82%	0.00%	0.00%	0.00%
Guayanilla	1.94%	1.40%	0.38%	0.00%	0.00%
Guaynabo	0.50%	1.41%	0.00%	0.00%	0.00%
Gurabo	1.72%	0.77%	0.00%	0.00%	0.00%
Hatillo	0.31%	1.28%	2.41%	1.23%	0.00%
Hormigueros	0.00%	0.25%	1.19%	0.00%	0.00%
Humacao	1.52%	1.90%	0.00%	0.00%	0.00%
Isabela	0.38%	1.71%	3.42%	1.12%	0.00%
Jayuya	0.00%	1.23%	3.85%	0.32%	0.00%
Juana Diaz	2.65%	2.10%	0.34%	0.00%	0.00%
Juncos	1.49%	0.79%	0.00%	0.00%	0.00%
Lajas	2.61%	2.27%	0.03%	0.00%	0.00%
Lares	0.00%	0.06%	3.08%	14.30%	12.25%
Las Marias	0.00%	0.00%	0.53%	13.32%	22.49%
Las Piedras	0.87%	1.58%	0.00%	0.00%	0.00%
Loiza	1.68%	0.32%	0.00%	0.00%	0.00%
Luquillo	0.40%	1.35%	0.00%	0.00%	0.00%
Manati	0.17%	2.52%	0.60%	0.00%	0.00%
Maricao	0.00%	0.00%	3.01%	6.75%	1.69%
Maunabo	1.61%	0.40%	0.00%	0.00%	0.00%
Mayaguez	2.59%	0.60%	5.91%	3.34%	0.00%
Moca	0.00%	0.08%	3.47%	9.73%	6.53%

Morovis	0.00%	1.60%	2.04%	0.00%	0.00%
Naguabo	1.23%	2.46%	0.02%	0.00%	0.00%
Naranjito	0.72%	1.29%	0.00%	0.00%	0.00%
Orocovis	0.06%	2.87%	2.53%	0.19%	0.00%
Patillas	2.73%	1.36%	0.00%	0.00%	0.00%
Penuelas	1.22%	1.77%	0.75%	0.00%	0.00%
Ponce	3.50%	4.67%	1.35%	0.00%	0.00%
Quebradillas	0.20%	0.85%	1.06%	0.33%	0.00%
Rincon	0.05%	0.27%	1.39%	0.40%	0.00%
Rio Grande	1.83%	2.65%	0.08%	0.00%	0.00%
Sabana Grande	0.16%	1.46%	1.64%	0.13%	0.00%
Salinas	6.14%	0.88%	0.00%	0.00%	0.00%
San German	0.10%	1.81%	3.52%	0.87%	0.00%
San Juan	1.72%	2.06%	0.00%	0.00%	0.00%
San Lorenzo	3.11%	1.52%	0.00%	0.00%	0.00%
San Sebastian	0.00%	0.02%	2.60%	14.16%	48.38%
Santa Isabel	2.42%	0.77%	0.00%	0.00%	0.00%
Toa Alta	0.13%	1.52%	0.20%	0.00%	0.00%
Toa Baja	0.27%	1.24%	0.14%	0.00%	0.00%
Trujillo Alto	1.26%	0.60%	0.00%	0.00%	0.00%
Utua	0.00%	0.61%	10.96%	14.63%	0.00%
Vega Alta	0.21%	1.47%	0.25%	0.00%	0.00%
Vega Baja	0.65%	2.37%	0.25%	0.00%	0.00%
Vieques	4.91%	0.54%	0.00%	0.00%	0.00%
Villalba	0.11%	1.95%	0.64%	0.00%	0.00%
Yabucoa	2.44%	2.02%	0.00%	0.00%	0.00%
Yauco	0.91%	2.29%	3.66%	0.18%	0.00%

Table 87: Lightning Hazard Scores and Ranks by Municipio

Municipio	Annual Lightning Hazard Frequency Score (Log Multiplied)		
	Total Score	Standardized Score (0-1)	Rank of Score (1-78)
San Sebastian	10,000.0336	1.0000	1
Las Marias	4,647.6530	0.4648	2
Lares	2,531.2702	0.2531	3
Anasco	1,753.2798	0.1753	4
Moca	1,349.8289	0.1350	5
Maricao	349.7474	0.0350	6
Aguada	38.6168	0.0038	7
Ponce	10.5691	0.0010	8
Arecibo	8.5872	0.0008	9
Coamo	8.0568	0.0008	9

Cabo Rojo	5.8465	0.0006	11
Orocovis	6.1454	0.0006	11
Rincon	5.9702	0.0006	11
Corozal	4.9027	0.0005	14
Juana Diaz	4.9321	0.0005	14
Lajas	5.2962	0.0005	14
Manati	5.4207	0.0005	14
Naguabo	5.4676	0.0005	14
Vega Baja	5.1914	0.0005	14
Yauco	5.0559	0.0005	14
Bayamon	4.6135	0.0004	21
Caguas	4.5129	0.0004	21
Humacao	4.3164	0.0004	21
Penuelas	3.9810	0.0004	21
San German	3.8940	0.0004	21
San Juan	4.6876	0.0004	21
San Lorenzo	3.7563	0.0004	21
Villalba	4.1873	0.0004	21
Yabucoa	4.7231	0.0004	21
Adjuntas	2.7973	0.0003	30
Barranquitas	3.6449	0.0003	30
Camuy	3.0536	0.0003	30
Cantano	2.8333	0.0003	30
Guanica	3.1513	0.0003	30
Guayanilla	3.3186	0.0003	30
Guaynabo	3.0946	0.0003	30
Hatillo	2.7883	0.0003	30
Isabela	3.7253	0.0003	30
Las Piedras	3.5177	0.0003	30
Luquillo	2.9508	0.0003	30
Morovis	3.4316	0.0003	30
Naranjito	2.8723	0.0003	30
Patillas	3.3649	0.0003	30
Sabana Grande	3.1641	0.0003	30
Salinas	2.8882	0.0003	30
Toa Alta	3.2859	0.0003	30
Vega Alta	3.1897	0.0003	30
Aguadilla	1.8801	0.0002	48
Aguas Buenas	2.3147	0.0002	48
Aibonito	2.2881	0.0002	48
Barceloneta	2.1192	0.0002	48
Canovanas	2.1515	0.0002	48

Cayey	2.1648	0.0002	48
Ceiba	2.4785	0.0002	48
Dorado	2.6502	0.0002	48
Fajardo	2.0615	0.0002	48
Guayama	2.6962	0.0002	48
Gurabo	1.9332	0.0002	48
Jayuya	2.6278	0.0002	48
Juncos	1.9447	0.0002	48
Quebradillas	1.8555	0.0002	48
Santa Isabel	2.0388	0.0002	48
Toa Baja	2.6999	0.0002	48
Vieques	1.9467	0.0002	48
Ciales	0.9788	0.0001	65
Cidra	1.4845	0.0001	65
Comerio	1.6947	0.0001	65
Florida	1.2662	0.0001	65
Loiza	0.9673	0.0001	65
Maunabo	1.1121	0.0001	65
Mayaguez	1.7001	0.0001	65
Trujillo Alto	1.4969	0.0001	65
Utuado	1.3108	0.0001	65
Arroyo	0.7025	0.0000	74
Carolina	0.5095	0.0000	74
Culebra	0.2398	0.0000	74
Hormigueros	0.5346	0.0000	74
Rjo Grande	0.5869	0.0000	74

Sea Level Rise

Hazard Overview

Sea level rise is an increase in the level of the world's oceans due to the effects of global warming and land subsidence. As ocean water becomes warmer, it expands. This results in ocean levels rising worldwide.⁴¹ Global sea level has been rising over the past century, and the rate has increased in recent decades. In 2014, global sea level was 2.6 inches above the 1993 average—the highest annual average in the satellite record (1993-present). Sea level continues to rise at a rate of about one-eighth of an inch per year.⁴² Sea level rise poses significant threat to people living and working in coastal areas.

Data and Methods

Three scenarios of future sea-level rise, created by NOAA⁴³, were utilized in this assessment: A low scenario (1 foot), A moderate scenario (4 feet), and a high scenario (10 feet) of sea level rise above Mean Higher High water levels.⁴⁴ Like flooding hazard, percentage of land area spatially inside NOAA SLR zones was calculated for each .5-mile hex grid across Puerto Rico. These were classified using an equal interval classifications scheme allowing users to clearly see where sea-level rise threatens the coastline.

Hazard Frequency Analysis Results

Like hurricane storm surges, sea level rise impacts are largely a coastal phenomena with the main island's northern shore northern shore seeing the heaviest potential impacts . However, impacts on all coastal Puerto Rico are clearly evident across all three scenarios with the 10 foot inundation creating the largest spatial impact (Figure 29, Figure 30, Figure 31). For each sea level rise scenario, the NOAA model indicates a differing amount of land area inundated in each municipio (Table 88, Table 92, Table 96). As a result, the percentage of each municipio's land area changes for each scenario (Table 89, Table 93, Table 97). The percent of each municipio's total island-wide land area also changes for different sea level rise scenarios (Table 90, Table 94, Table 98). Finally, a table showing municipio scores and ranks for each scenario provides perspective on which areas of the island are more highly threatened by potential sea level rise conditions (Table 91, Table 95, Table 99).

⁴¹ <https://www.nationalgeographic.org/encyclopedia/sea-level-rise/>

⁴² <https://oceanservice.noaa.gov/facts/sealevel.html>

⁴³ <https://coast.noaa.gov/slrdata/>

⁴⁴ https://tidesandcurrents.noaa.gov/datum_options.html

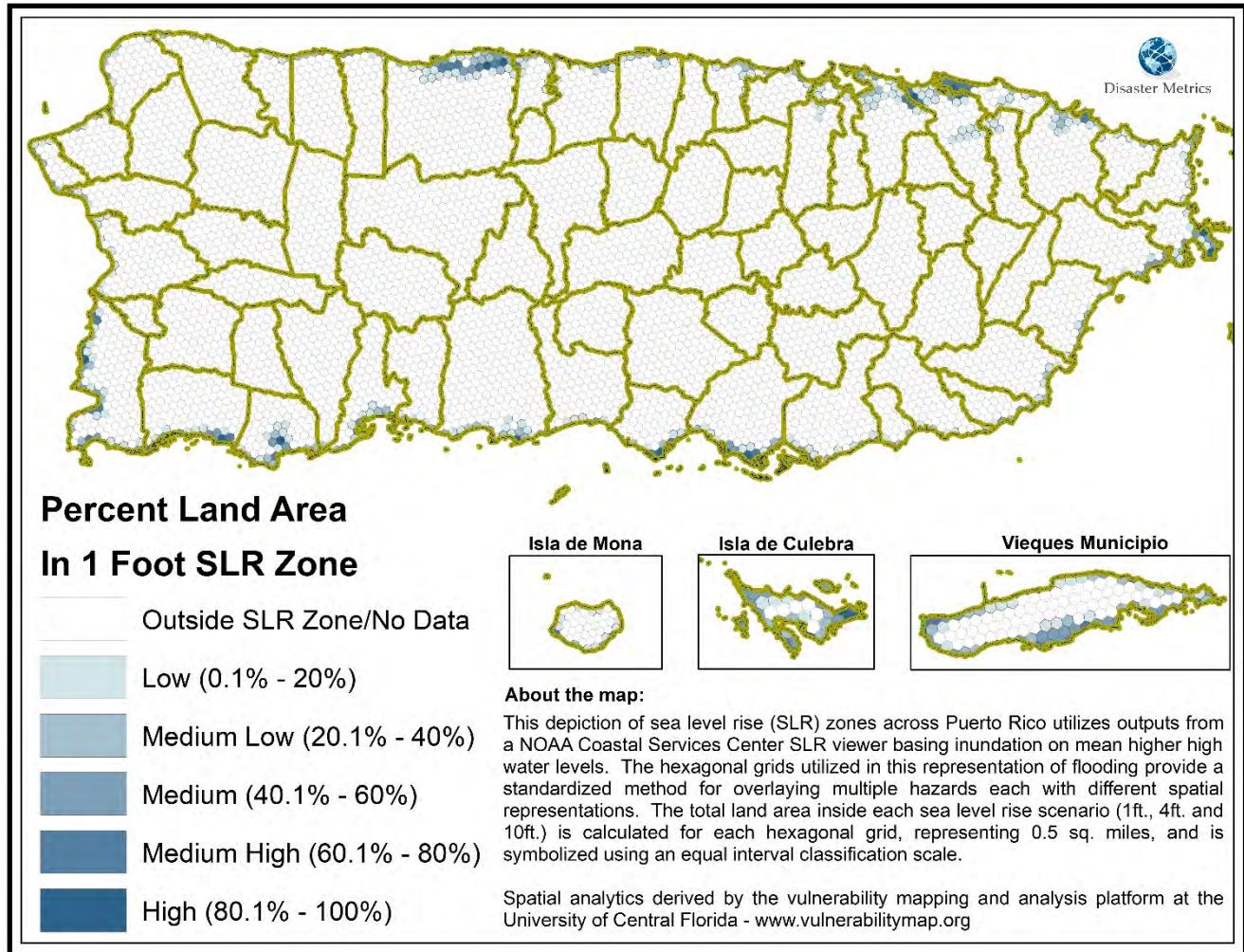


Figure 29: Sea Level Rise (1 foot) Hazard Areas

Table 88: Sea Level Rise (1 foot) by Municipio and Areal Extent

Municipio	Hex Grid Area in Sea Level Rise (1 Foot) Zones (Sq. miles)					
	No SLR/No Data	Low (< 20%)	Medium Low (20.1% - 40%)	Medium (40.1% - 60%)	Medium High (60.1% - 80%)	High (80.1% - 100%)
Adjuntas	67.10					
Aguada	28.57	1.11	0.68		0.43	0.13
Aguadilla	32.16	2.27	1.06	0.31	0.67	0.14
Aguas Buenas	30.10					
Aibonito	31.34					
Anasco	37.32	1.41	0.32	0.45		0.06
Arecibo	107.06	9.44	3.47	2.88	2.73	1.39
Arroyo	13.41	0.48	0.68	0.26	0.15	0.06
Barceloneta	13.53	3.42	1.25		0.52	0.03
Barranquitas	34.28					
Bayamon	42.59	1.92				

Cabo Rojo	54.95	6.55	3.27	2.84	3.76	1.75
Caguas	59.07					
Camuy	44.60	0.29	1.18	0.22		0.08
Canovanas	30.05	2.96				
Cantano	34.64	8.61	0.45	0.80	1.86	0.94
Carolina	1.99	2.24	0.43	0.32	0.06	0.04
Cayey	51.96					
Ceiba	20.30	2.99	0.46	3.05	1.35	2.22
Ciales	66.71					
Cidra	36.46					
Coamo	78.03					
Comerio	28.52					
Corozal	42.58					
Culebra	3.00	1.90	2.25	3.31	1.48	1.37
Dorado	18.38	2.35	1.60	0.71	0.12	0.25
Fajardo	24.46	1.93	1.36	1.26	0.89	0.61
Florida	15.22					
Guanica	28.76	4.09	2.71	1.32	1.27	0.85
Guayama	58.00	3.84	0.34	1.05	0.79	1.85
Guayanilla	36.52	2.44	1.69	0.90	0.96	0.49
Guaynabo	26.85	0.61		0.22	0.08	
Gurabo	28.31					
Hatillo	39.75	0.88		1.05	0.15	0.01
Hormigueros	11.34					
Humacao	40.81	1.60	1.24	1.03	0.21	0.21
Isabela	52.06	1.71	0.66	0.43	0.18	0.37
Jayuya	44.53					
Juana Diaz	57.48	1.89	0.41	0.27	0.39	0.30
Juncos	26.62					
Lajas	53.57	3.22		1.87	1.79	0.92
Lares	61.64					
Las Marias	46.51					
Las Piedras	33.89					
Loiza	12.04	2.99	0.76	1.11	2.66	0.96
Luquillo	22.60	2.28	0.46	0.04	0.19	0.29
Manati	41.67	2.97	0.84	0.29	0.59	0.46
Maricao	36.63					
Maunabo	19.14	0.48	0.68	0.61	0.09	0.07
Mayaguez	64.16	9.54	0.35	0.33	2.72	0.87
Moca	50.37					
Morovis	38.93					
Naguabo	47.83	1.30	0.41	1.96	0.14	0.25

Naranjito	27.75					
Orocovis	63.78					
Patillas	44.14	1.37	0.36	0.41	0.85	0.09
Penuelas	41.97	1.33	0.64		0.56	0.25
Ponce	107.43	4.78	2.63	0.74	0.27	1.14
Quebradillas	21.42	0.94	0.25	0.21	0.32	0.00
Rio Grande	11.01	1.42	0.75	0.79	0.17	0.25
Rincon	52.65	3.99	2.38	0.25	1.11	0.44
Sabana Grande	35.84					
Salinas	61.14	2.86	1.03	1.57	1.01	2.45
San German	54.51					
San Juan	37.18	7.15	2.10	1.28	1.40	0.42
San Lorenzo	53.21					
San Sebastian	71.22					
Santa Isabel	29.32	1.47	1.23		1.50	1.07
Toa Alta	27.56					
Toa Baja	19.97	2.29	0.67	0.35	0.10	0.42
Trujillo Alto	21.38					
Utua	115.07					
Vega Alta	26.83	0.19	0.32	0.30		0.09
Vega Baja	42.70	2.21	0.75	0.71	0.16	0.12
Vieques	30.00	7.17	5.08	6.91	3.12	0.90
Villalba	37.04					
Yabucoa	51.64	1.90	1.02	0.22	0.61	0.02
Yauco	68.37		0.43			0.02
Grand Total	3181.48	128.80	48.66	42.62	37.43	24.64

Table 89: Percent of (Municipio) Hexagonal Area by Sea Level Rise (1 foot) per Municipio

Municipio	Sea Level Rise (1 Foot) Percent Area by Total (Municipio) Land Area					
	No SLR/No Data	Low (< 20%)	Medium Low (20.1% - 40%)	Medium (40.1% - 60%)	Medium High (60.1% - 80%)	High (80.1% - 100%)
Adjuntas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Aguada	92.39%	3.58%	2.21%	0.00%	1.39%	0.42%
Aguadilla	87.86%	6.21%	2.90%	0.84%	1.82%	0.37%
Agua Buenas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Aibonito	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Anasco	94.35%	3.56%	0.82%	1.13%	0.00%	0.14%
Arecibo	84.31%	7.44%	2.73%	2.27%	2.15%	1.09%
Arroyo	89.12%	3.19%	4.52%	1.74%	1.01%	0.43%
Barceloneta	72.14%	18.25%	6.68%	0.00%	2.78%	0.15%
Barranquitas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Bayamon	95.68%	4.32%	0.00%	0.00%	0.00%	0.00%
Cabo Rojo	75.15%	8.96%	4.47%	3.88%	5.15%	2.39%
Caguas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Camuy	96.17%	0.63%	2.55%	0.48%	0.00%	0.17%
Canovanas	91.03%	8.97%	0.00%	0.00%	0.00%	0.00%
Cantano	73.23%	18.20%	0.95%	1.70%	3.94%	1.99%
Carolina	39.17%	44.09%	8.42%	6.34%	1.17%	0.80%
Cayey	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Ceiba	66.83%	9.86%	1.51%	10.05%	4.45%	7.31%
Ciales	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Cidra	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Coamo	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Comerio	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Corozal	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Culebra	22.54%	14.28%	16.90%	24.89%	11.11%	10.28%
Dorado	78.50%	10.02%	6.84%	3.03%	0.53%	1.09%
Fajardo	80.17%	6.34%	4.44%	4.13%	2.93%	1.99%
Florida	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Guanica	73.72%	10.49%	6.95%	3.39%	3.27%	2.18%
Guayama	88.05%	5.84%	0.51%	1.59%	1.20%	2.81%
Guayanilla	84.95%	5.67%	3.92%	2.10%	2.23%	1.13%
Guaynabo	96.71%	2.21%	0.00%	0.79%	0.29%	0.00%
Gurabo	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Hatillo	95.00%	2.10%	0.00%	2.51%	0.36%	0.02%
Hormigueros	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Humacao	90.48%	3.54%	2.76%	2.28%	0.47%	0.47%
Isabela	93.95%	3.09%	1.19%	0.77%	0.32%	0.67%
Jayuya	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Juana Diaz	94.64%	3.11%	0.68%	0.45%	0.64%	0.49%
Juncos	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lajas	87.30%	5.24%	0.00%	3.05%	2.92%	1.49%
Lares	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Marias	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Piedras	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Loiza	58.66%	14.58%	3.72%	5.43%	12.94%	4.68%
Luquillo	87.38%	8.82%	1.80%	0.14%	0.74%	1.12%
Manati	89.00%	6.33%	1.80%	0.62%	1.26%	0.98%
Maricao	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Maunabo	90.78%	2.30%	3.23%	2.91%	0.45%	0.34%
Mayaguez	82.29%	12.23%	0.45%	0.42%	3.49%	1.12%
Moca	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Morovis	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Naguabo	92.19%	2.50%	0.78%	3.78%	0.27%	0.49%
Naranjito	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Orocovis	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Patillas	93.49%	2.89%	0.76%	0.87%	1.79%	0.20%
Penuelas	93.78%	2.98%	1.43%	0.00%	1.25%	0.56%
Ponce	91.84%	4.09%	2.24%	0.63%	0.23%	0.97%
Quebradillas	92.58%	4.06%	1.07%	0.89%	1.40%	0.01%
Rio Grande	76.53%	9.86%	5.22%	5.50%	1.18%	1.71%
Rincon	86.57%	6.56%	3.91%	0.41%	1.82%	0.73%
Sabana Grande	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Salinas	87.27%	4.09%	1.47%	2.24%	1.45%	3.49%
San German	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
San Juan	75.07%	14.44%	4.24%	2.59%	2.83%	0.85%
San Lorenzo	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
San Sebastian	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Santa Isabel	84.80%	4.25%	3.55%	0.00%	4.33%	3.08%
Toa Alta	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Toa Baja	83.90%	9.61%	2.83%	1.48%	0.41%	1.78%
Trujillo Alto	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Utua	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Vega Alta	96.72%	0.70%	1.16%	1.08%	0.00%	0.34%
Vega Baja	91.54%	4.74%	1.60%	1.51%	0.35%	0.26%
Vieques	56.41%	13.48%	9.56%	13.00%	5.87%	1.69%
Villalba	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Yabucoa	93.19%	3.44%	1.84%	0.39%	1.11%	0.03%
Yauco	99.35%	0.00%	0.63%	0.00%	0.00%	0.02%

Table 90: Percent of (Island) Hexagonal Area by Sea Level Rise (1 foot) per Municipio

Municipio	Sea Level Rise (1 Foot) Percent Area by Total (Island) Land Area					
	No SLR/No Data	Low (< 20%)	Medium Low (20.1% - 40%)	Medium (40.1% - 60%)	Medium High (60.1% - 80%)	High (80.1% - 100%)
Adjuntas	2.11%	0.00%	0.00%	0.00%	0.00%	0.00%
Aguada	0.90%	0.86%	1.41%	0.00%	1.15%	0.52%
Aguadilla	1.01%	1.77%	2.18%	0.72%	1.78%	0.55%
Agua Buenas	0.95%	0.00%	0.00%	0.00%	0.00%	0.00%
Aibonito	0.99%	0.00%	0.00%	0.00%	0.00%	0.00%
Anasco	1.17%	1.09%	0.67%	1.05%	0.00%	0.23%
Arecibo	3.36%	7.33%	7.14%	6.76%	7.30%	5.64%
Arroyo	0.42%	0.37%	1.40%	0.61%	0.41%	0.26%
Barceloneta	0.43%	2.66%	2.57%	0.00%	1.40%	0.11%
Barranquitas	1.08%	0.00%	0.00%	0.00%	0.00%	0.00%

Bayamon	1.34%	1.49%	0.00%	0.00%	0.00%	0.00%
Cabo Rojo	1.73%	5.09%	6.72%	6.65%	10.06%	7.11%
Caguas	1.86%	0.00%	0.00%	0.00%	0.00%	0.00%
Camuy	1.40%	0.23%	2.43%	0.52%	0.00%	0.33%
Canovanas	0.94%	2.30%	0.00%	0.00%	0.00%	0.00%
Cantano	1.09%	6.68%	0.92%	1.88%	4.98%	3.81%
Carolina	0.06%	1.74%	0.88%	0.76%	0.16%	0.16%
Cayey	1.63%	0.00%	0.00%	0.00%	0.00%	0.00%
Ceiba	0.64%	2.33%	0.94%	7.16%	3.61%	9.01%
Ciales	2.10%	0.00%	0.00%	0.00%	0.00%	0.00%
Cidra	1.15%	0.00%	0.00%	0.00%	0.00%	0.00%
Coamo	2.45%	0.00%	0.00%	0.00%	0.00%	0.00%
Comerio	0.90%	0.00%	0.00%	0.00%	0.00%	0.00%
Corozal	1.34%	0.00%	0.00%	0.00%	0.00%	0.00%
Culebra	0.09%	1.47%	4.62%	7.77%	3.95%	5.55%
Dorado	0.58%	1.82%	3.29%	1.66%	0.33%	1.03%
Fajardo	0.77%	1.50%	2.79%	2.96%	2.39%	2.47%
Florida	0.48%	0.00%	0.00%	0.00%	0.00%	0.00%
Guanica	0.90%	3.18%	5.57%	3.10%	3.41%	3.45%
Guayama	1.82%	2.98%	0.69%	2.46%	2.11%	7.51%
Guayanilla	1.15%	1.89%	3.47%	2.11%	2.56%	1.97%
Guaynabo	0.84%	0.48%	0.00%	0.52%	0.22%	0.00%
Gurabo	0.89%	0.00%	0.00%	0.00%	0.00%	0.00%
Hatillo	1.25%	0.68%	0.00%	2.47%	0.41%	0.04%
Hormigueros	0.36%	0.00%	0.00%	0.00%	0.00%	0.00%
Humacao	1.28%	1.24%	2.55%	2.41%	0.57%	0.86%
Isabela	1.64%	1.33%	1.36%	1.01%	0.47%	1.51%
Jayuya	1.40%	0.00%	0.00%	0.00%	0.00%	0.00%
Juana Diaz	1.81%	1.46%	0.85%	0.64%	1.03%	1.22%
Juncos	0.84%	0.00%	0.00%	0.00%	0.00%	0.00%
Lajas	1.68%	2.50%	0.00%	4.39%	4.78%	3.72%
Lares	1.94%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Marias	1.46%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Piedras	1.07%	0.00%	0.00%	0.00%	0.00%	0.00%
Loiza	0.38%	2.32%	1.57%	2.61%	7.10%	3.90%
Luquillo	0.71%	1.77%	0.95%	0.09%	0.51%	1.18%
Manati	1.31%	2.30%	1.73%	0.68%	1.58%	1.86%
Maricao	1.15%	0.00%	0.00%	0.00%	0.00%	0.00%
Maunabo	0.60%	0.38%	1.40%	1.44%	0.25%	0.29%
Mayaguez	2.02%	7.41%	0.73%	0.77%	7.27%	3.54%
Moca	1.58%	0.00%	0.00%	0.00%	0.00%	0.00%
Morovis	1.22%	0.00%	0.00%	0.00%	0.00%	0.00%

Naguabo	1.50%	1.01%	0.84%	4.60%	0.37%	1.02%
Naranjito	0.87%	0.00%	0.00%	0.00%	0.00%	0.00%
Orocovis	2.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Patillas	1.39%	1.06%	0.73%	0.96%	2.26%	0.38%
Penuelas	1.32%	1.03%	1.32%	0.00%	1.49%	1.03%
Ponce	3.38%	3.71%	5.39%	1.73%	0.72%	4.63%
Quebradillas	0.67%	0.73%	0.51%	0.48%	0.86%	0.01%
Rjo Grande	0.35%	1.10%	1.54%	1.86%	0.45%	1.00%
Rincon	1.65%	3.10%	4.89%	0.58%	2.96%	1.79%
Sabana Grande	1.13%	0.00%	0.00%	0.00%	0.00%	0.00%
Salinas	1.92%	2.22%	2.11%	3.68%	2.71%	9.93%
San German	1.71%	0.00%	0.00%	0.00%	0.00%	0.00%
San Juan	1.17%	5.55%	4.31%	3.00%	3.74%	1.71%
San Lorenzo	1.67%	0.00%	0.00%	0.00%	0.00%	0.00%
San Sebastian	2.24%	0.00%	0.00%	0.00%	0.00%	0.00%
Santa Isabel	0.92%	1.14%	2.52%	0.00%	4.00%	4.32%
Toa Alta	0.87%	0.00%	0.00%	0.00%	0.00%	0.00%
Toa Baja	0.63%	1.78%	1.38%	0.83%	0.26%	1.72%
Trujillo Alto	0.67%	0.00%	0.00%	0.00%	0.00%	0.00%
Utua	3.62%	0.00%	0.00%	0.00%	0.00%	0.00%
Vega Alta	0.84%	0.15%	0.66%	0.70%	0.00%	0.38%
Vega Baja	1.34%	1.72%	1.53%	1.66%	0.43%	0.49%
Vieques	0.94%	5.57%	10.45%	16.22%	8.33%	3.64%
Villalba	1.16%	0.00%	0.00%	0.00%	0.00%	0.00%
Yabucoa	1.62%	1.48%	2.10%	0.51%	1.64%	0.07%
Yauco	2.15%	0.00%	0.89%	0.00%	0.00%	0.06%

Table 91: Sea Level Rise (1 foot) Hazard Scores and Ranks by Municipio

Municipio	Sea Level Rise (1 Foot) Hazard Score (Log Multiplied)		
	Total Score	Standardized Score (0-1)	Rank of Score (1 – 78)
Salinas	10294.4028	1.0000	1
Ceiba	9477.9994	0.9207	2
Cabo Rojo	8208.1394	0.7973	3
Guayama	7789.1656	0.7566	4
Arecibo	6459.5595	0.6275	5
Culebra	6039.1213	0.5866	6
Santa Isabel	4756.6444	0.4621	7
Ponce	4750.1998	0.4614	8
Loiza	4651.3864	0.4518	9
Vieques	4609.7075	0.4478	10
Carolina	4350.4366	0.4226	11

Mayaguez	4291.4889	0.4169	12
Lajas	4253.4350	0.4132	13
Guanica	3834.5888	0.3725	14
Fajardo	2742.4092	0.2664	15
Guayanilla	2255.8893	0.2191	16
San Juan	2115.4358	0.2055	17
Rio Grande	2107.5262	0.2047	18
Manati	2037.6867	0.1979	19
Toa Baja	1761.5795	0.1711	20
Isabela	1575.1355	0.1530	21
Juana Diaz	1334.1222	0.1296	22
Luquillo	1240.0682	0.1205	23
Penuelas	1182.3569	0.1149	24
Naguabo	1096.6388	0.1065	25
Dorado	1087.9311	0.1057	26
Rincon	1065.7416	0.1035	27
Humacao	940.8153	0.0914	28
Aguadilla	738.6460	0.0718	29
Aguada	642.0512	0.0624	30
Patillas	610.4918	0.0593	31
Vega Baja	549.3412	0.0534	32
Vega Alta	388.2917	0.0377	33
Camuy	334.8779	0.0325	34
Maunabo	325.3957	0.0316	35
Arroyo	309.8169	0.0301	36
Barceloneta	254.7122	0.0247	37
Yabucoa	242.7397	0.0236	38
Anasco	235.6831	0.0229	39
Catano	187.0706	0.0182	40
Quebradillas	100.0748	0.0097	41
Hatillo	97.1815	0.0094	42
Yauco	66.0656	0.0064	43
Guaynabo	24.9213	0.0024	44
Adjuntas	0.0000	0.0000	45
Aguas Buenas	0.0000	0.0000	45
Aibonito	0.0000	0.0000	45
Barranquitas	0.0000	0.0000	45
Bayamon	0.2015	0.0000	45
Caguas	0.0000	0.0000	45
Canovanas	0.3102	0.0000	45
Cayey	0.0000	0.0000	45
Ciales	0.0000	0.0000	45

Cidra	0.0000	0.0000	45
Coamo	0.0000	0.0000	45
Comerio	0.0000	0.0000	45
Corozal	0.0000	0.0000	45
Florida	0.0000	0.0000	45
Gurabo	0.0000	0.0000	45
Hormigueros	0.0000	0.0000	45
Jayuya	0.0000	0.0000	45
Juncos	0.0000	0.0000	45
Lares	0.0000	0.0000	45
Las Marias	0.0000	0.0000	45
Las Piedras	0.0000	0.0000	45
Maricao	0.0000	0.0000	45
Moca	0.0000	0.0000	45
Morovis	0.0000	0.0000	45
Naranjito	0.0000	0.0000	45
Orocovis	0.0000	0.0000	45
Sabana Grande	0.0000	0.0000	45
San German	0.0000	0.0000	45
San Lorenzo	0.0000	0.0000	45
San Sebastian	0.0000	0.0000	45
Toa Alta	0.0000	0.0000	45
Trujillo Alto	0.0000	0.0000	45
Utua	0.0000	0.0000	45
Villalba	0.0000	0.0000	45

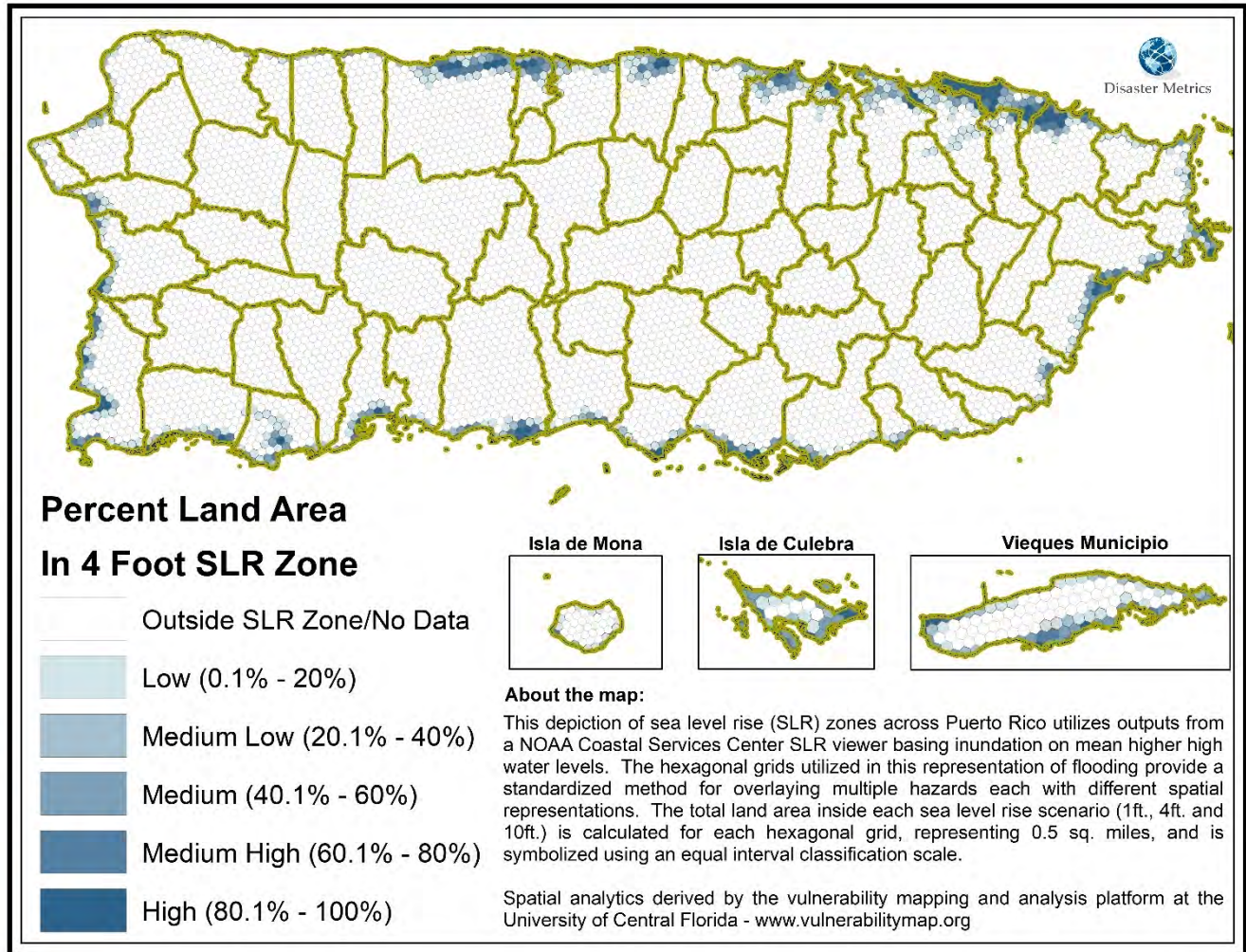


Figure 30: Sea Level Rise (4 feet) Hazard Areas

Table 92: Sea Level Rise (4 feet) by Municipio and Areal Extent

Municipio	Hex Grid Area in Sea Level Rise (4 Feet) Zones (Sq. miles)					
	No SLR/No Date	Low (< 20%)	Medium Low (20.1% - 40%)	Medium (40.1% - 60%)	Medium High (60.1% - 80%)	High (80.1% - 100%)
Adjuntas	67.10					
Aguada	27.07	1.13	1.80	0.36	0.33	0.23
Aguadilla	31.66	2.77	1.06	0.31	0.64	0.16
Aguas Buenas	30.10					
Aibonito	31.34					
Anasco	33.83	2.92	0.50	0.86	1.25	0.21
Arecibo	105.56	8.01	3.69	1.95	4.14	3.62
Arroyo	12.03	1.36	0.50	0.31	0.67	0.17
Barceloneta	9.48	2.84	1.31	2.08	1.65	1.40
Barranquitas	34.28					
Bayamon	41.96	2.56				

Cabo Rojo	49.90	9.08	2.24	2.77	3.66	5.46
Caguas	59.07					
Camuy	44.49	0.10	1.47	0.22		0.08
Canovanas	28.16	3.30	0.66		0.52	0.37
Cantano	28.65	10.91	2.35	0.97	1.62	2.79
Carolina		2.86	0.11	0.70	0.66	0.76
Cayey	51.96					
Ceiba	19.46	2.83	1.00	2.16	1.41	3.51
Ciales	66.71					
Cidra	36.46					
Coamo	78.03					
Comerio	28.52					
Corozal	42.58					
Culebra	2.50	2.40	1.05	4.26	1.73	1.37
Dorado	16.93	3.01	1.37	1.45	0.26	0.40
Fajardo	21.96	3.45	1.15	1.17	1.56	1.22
Florida	15.22					
Guanica	25.21	7.14	1.51	3.03	1.20	0.92
Guayama	57.50	2.94	0.50	1.18	1.49	2.26
Guayanilla	35.02	2.03	0.86	2.06	1.04	1.98
Guaynabo	26.48	0.90		0.08	0.30	
Gurabo	28.31					
Hatillo	39.35	1.17	0.11	1.05	0.15	0.01
Hormigueros	11.34					
Humacao	34.09	3.49	1.52	2.03	1.92	2.06
Isabela	51.21	2.16	1.05	0.24	0.37	0.37
Jayuya	44.53					
Juana Diaz	55.45	2.52	0.50	0.50	1.02	0.75
Juncos	26.62					
Lajas	52.66	3.21	0.92	1.21	1.36	2.00
Lares	61.64					
Las Marias	46.51					
Las Piedras	33.89					
Loiza	1.12	1.68	2.25	2.90	2.44	10.15
Luquillo	21.60	3.28	0.35		0.34	0.29
Manati	39.23	4.13	1.81	0.61	0.59	0.46
Maricao	36.63					
Maunabo	19.14	0.48	0.68	0.61	0.09	0.07
Mayaguez	61.66	9.01	1.74	0.64	3.05	1.87
Moca	50.37					
Morovis	38.93					
Naguabo	44.88	1.17	0.93	1.31	2.58	1.02

Naranjito	27.75					
Orocovis	63.78					
Patillas	44.02	0.63	0.77	0.64	0.74	0.41
Penuelas	41.47	0.97	0.74	0.77	0.56	0.25
Ponce	104.43	3.47	2.23	0.89	3.15	2.81
Quebradillas	21.27	1.09	0.25	0.21	0.32	0.00
Rio Grande	11.01	1.42	0.75	0.79	0.17	0.25
Rincon	48.24	2.06	1.93	1.46	2.43	4.69
Sabana Grande	35.84					
Salinas	60.64	1.46	2.02	1.19	1.28	3.46
San German	54.51					
San Juan	35.67	5.74	3.59	2.33	0.86	1.33
San Lorenzo	53.21					
San Sebastian	71.22					
Santa Isabel	27.36	2.43	2.12		0.26	2.41
Toa Alta	27.56					
Toa Baja	11.43	5.62	1.61	2.21	1.96	0.98
Trujillo Alto	20.09	1.29				
Utua	115.07					
Vega Alta	26.83	0.19	0.32	0.30		0.09
Vega Baja	35.20	4.71	2.25	2.29	0.66	1.53
Vieques	28.50	8.25	4.01	6.29	3.95	2.19
Villalba	37.04					
Yabucoa	50.14	2.40	1.04	0.70	1.02	0.11
Yauco	68.37		0.43			0.02
Grand Total	3078.99	146.57	59.04	57.12	55.42	66.50

Table 93: Percent of (Municipio) Hexagonal Area by Sea Level Rise (4 feet) per Municipio

Municipio	Sea Level Rise (4 Feet) Percent Area by Total (Municipio) Land Area					
	No SLR/No Data	Low (< 20%)	Medium Low (20.1% - 40%)	Medium (40.1% - 60%)	Medium High (60.1% - 80%)	High (80.1% - 100%)
Adjuntas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Aguada	87.54%	3.66%	5.81%	1.18%	1.07%	0.74%
Aguadilla	86.50%	7.57%	2.90%	0.84%	1.76%	0.43%
Aguas Buenas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Aibonito	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Anasco	85.51%	7.38%	1.26%	2.17%	3.16%	0.52%
Arecibo	83.13%	6.31%	2.90%	1.54%	3.26%	2.85%
Arroyo	79.97%	9.02%	3.32%	2.08%	4.46%	1.15%
Barceloneta	50.54%	15.12%	6.98%	11.09%	8.78%	7.48%
Barranquitas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Bayamon	94.26%	5.74%	0.00%	0.00%	0.00%	0.00%
Cabo Rojo	68.25%	12.42%	3.06%	3.79%	5.00%	7.47%
Caguas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Camuy	95.95%	0.22%	3.17%	0.48%	0.00%	0.17%
Canovanas	85.32%	9.99%	2.00%	0.00%	1.57%	1.12%
Cantano	60.57%	23.07%	4.98%	2.06%	3.43%	5.89%
Carolina	0.00%	56.17%	2.16%	13.69%	12.96%	15.02%
Cayey	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Ceiba	64.07%	9.32%	3.29%	7.10%	4.65%	11.55%
Ciales	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Cidra	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Coamo	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Comerio	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Corozal	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Culebra	18.79%	18.03%	7.90%	32.01%	12.99%	10.28%
Dorado	72.29%	12.85%	5.84%	6.21%	1.11%	1.70%
Fajardo	71.97%	11.32%	3.76%	3.84%	5.10%	4.01%
Florida	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Guanica	64.63%	18.30%	3.86%	7.76%	3.08%	2.37%
Guayama	87.29%	4.46%	0.76%	1.79%	2.27%	3.43%
Guayanilla	81.46%	4.72%	2.01%	4.79%	2.41%	4.61%
Guaynabo	95.36%	3.26%	0.00%	0.30%	1.09%	0.00%
Gurabo	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Hatillo	94.05%	2.79%	0.26%	2.51%	0.36%	0.02%
Hormigueros	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Humacao	75.59%	7.74%	3.36%	4.50%	4.26%	4.56%
Isabela	92.43%	3.90%	1.90%	0.43%	0.66%	0.67%
Jayuya	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Juana Diaz	91.30%	4.14%	0.82%	0.82%	1.69%	1.23%
Juncos	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lajas	85.82%	5.23%	1.49%	1.97%	2.22%	3.27%
Lares	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Marias	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Piedras	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Loiza	5.45%	8.17%	10.95%	14.14%	11.88%	49.41%
Luquillo	83.51%	12.69%	1.35%	0.00%	1.32%	1.12%
Manati	83.78%	8.82%	3.86%	1.30%	1.26%	0.98%
Maricao	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Maunabo	90.78%	2.30%	3.23%	2.91%	0.45%	0.34%
Mayaguez	79.08%	11.56%	2.23%	0.82%	3.91%	2.40%
Moca	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Morovis	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Naguabo	86.51%	2.25%	1.79%	2.53%	4.97%	1.96%
Naranjito	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Orocovis	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Patillas	93.23%	1.34%	1.63%	1.36%	1.57%	0.87%
Penuelas	92.66%	2.16%	1.65%	1.72%	1.25%	0.56%
Ponce	89.27%	2.96%	1.91%	0.76%	2.69%	2.40%
Quebradillas	91.90%	4.73%	1.08%	0.89%	1.40%	0.01%
Rio Grande	76.53%	9.86%	5.22%	5.50%	1.18%	1.71%
Rincon	79.32%	3.38%	3.18%	2.40%	3.99%	7.72%
Sabana Grande	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Salinas	86.56%	2.09%	2.88%	1.70%	1.83%	4.94%
San German	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
San Juan	72.03%	11.58%	7.25%	4.70%	1.74%	2.69%
San Lorenzo	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
San Sebastian	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Santa Isabel	79.14%	7.02%	6.14%	0.00%	0.75%	6.96%
Toa Alta	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Toa Baja	48.00%	23.63%	6.76%	9.28%	8.23%	4.10%
Trujillo Alto	93.98%	6.02%	0.00%	0.00%	0.00%	0.00%
Utua	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Vega Alta	96.72%	0.70%	1.16%	1.08%	0.00%	0.34%
Vega Baja	75.46%	10.10%	4.82%	4.91%	1.42%	3.29%
Vieques	53.59%	15.51%	7.54%	11.84%	7.42%	4.11%
Villalba	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Yabucoa	90.49%	4.34%	1.88%	1.25%	1.84%	0.21%
Yauco	99.35%	0.00%	0.63%	0.00%	0.00%	0.02%

Table 94: Percent of (Island) Hexagonal Area by Sea Level Rise (4 feet) per Municipio

Municipio	Sea Level Rise (4 Feet) Percent Area by Total (Island) Land Area					
	No SLR/No Data	Low (< 20%)	Medium Low (20.1% - 40%)	Medium (40.1% - 60%)	Medium High (60.1% - 80%)	High (80.1% - 100%)
Adjuntas	2.18%	0.00%	0.00%	0.00%	0.00%	0.00%
Aguada	0.88%	0.77%	3.04%	0.64%	0.60%	0.34%
Aguadilla	1.03%	1.89%	1.80%	0.54%	1.16%	0.24%
Aguas Buenas	0.98%	0.00%	0.00%	0.00%	0.00%	0.00%
Aibonito	1.02%	0.00%	0.00%	0.00%	0.00%	0.00%
Anasco	1.10%	1.99%	0.85%	1.50%	2.26%	0.31%
Arecibo	3.43%	5.47%	6.24%	3.42%	7.48%	5.45%
Arroyo	0.39%	0.93%	0.85%	0.55%	1.21%	0.26%
Barceloneta	0.31%	1.94%	2.22%	3.64%	2.97%	2.11%
Barranquitas	1.11%	0.00%	0.00%	0.00%	0.00%	0.00%

Bayamon	1.36%	1.74%	0.00%	0.00%	0.00%	0.00%
Cabo Rojo	1.62%	6.20%	3.79%	4.85%	6.60%	8.21%
Caguas	1.92%	0.00%	0.00%	0.00%	0.00%	0.00%
Camuy	1.45%	0.07%	2.49%	0.39%	0.00%	0.12%
Canovanas	0.91%	2.25%	1.12%	0.00%	0.93%	0.56%
Cantano	0.93%	7.45%	3.99%	1.71%	2.93%	4.19%
Carolina	0.00%	1.95%	0.19%	1.22%	1.19%	1.15%
Cayey	1.69%	0.00%	0.00%	0.00%	0.00%	0.00%
Ceiba	0.63%	1.93%	1.69%	3.78%	2.55%	5.28%
Ciales	2.17%	0.00%	0.00%	0.00%	0.00%	0.00%
Cidra	1.18%	0.00%	0.00%	0.00%	0.00%	0.00%
Coamo	2.53%	0.00%	0.00%	0.00%	0.00%	0.00%
Comerio	0.93%	0.00%	0.00%	0.00%	0.00%	0.00%
Corozal	1.38%	0.00%	0.00%	0.00%	0.00%	0.00%
Culebra	0.08%	1.64%	1.78%	7.46%	3.12%	2.06%
Dorado	0.55%	2.05%	2.32%	2.54%	0.47%	0.60%
Fajardo	0.71%	2.36%	1.95%	2.05%	2.81%	1.84%
Florida	0.49%	0.00%	0.00%	0.00%	0.00%	0.00%
Guanica	0.82%	4.87%	2.55%	5.30%	2.17%	1.39%
Guayama	1.87%	2.00%	0.85%	2.06%	2.69%	3.40%
Guayanilla	1.14%	1.38%	1.46%	3.61%	1.87%	2.98%
Guaynabo	0.86%	0.62%	0.00%	0.15%	0.54%	0.00%
Gurabo	0.92%	0.00%	0.00%	0.00%	0.00%	0.00%
Hatillo	1.28%	0.80%	0.18%	1.84%	0.27%	0.02%
Hormigueros	0.37%	0.00%	0.00%	0.00%	0.00%	0.00%
Humacao	1.11%	2.38%	2.57%	3.55%	3.47%	3.09%
Isabela	1.66%	1.48%	1.79%	0.42%	0.66%	0.56%
Jayuya	1.45%	0.00%	0.00%	0.00%	0.00%	0.00%
Juana Diaz	1.80%	1.72%	0.84%	0.88%	1.85%	1.13%
Juncos	0.86%	0.00%	0.00%	0.00%	0.00%	0.00%
Lajas	1.71%	2.19%	1.55%	2.11%	2.46%	3.01%
Lares	2.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Marias	1.51%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Piedras	1.10%	0.00%	0.00%	0.00%	0.00%	0.00%
Loiza	0.04%	1.14%	3.81%	5.08%	4.40%	15.26%
Luquillo	0.70%	2.24%	0.59%	0.00%	0.62%	0.44%
Manati	1.27%	2.82%	3.06%	1.06%	1.07%	0.69%
Maricao	1.19%	0.00%	0.00%	0.00%	0.00%	0.00%
Maunabo	0.62%	0.33%	1.16%	1.07%	0.17%	0.11%
Mayaguez	2.00%	6.15%	2.94%	1.13%	5.50%	2.82%
Moca	1.64%	0.00%	0.00%	0.00%	0.00%	0.00%
Morovis	1.26%	0.00%	0.00%	0.00%	0.00%	0.00%

Naguabo	1.46%	0.80%	1.57%	2.29%	4.65%	1.53%
Naranjito	0.90%	0.00%	0.00%	0.00%	0.00%	0.00%
Orocovis	2.07%	0.00%	0.00%	0.00%	0.00%	0.00%
Patillas	1.43%	0.43%	1.30%	1.13%	1.33%	0.62%
Penuelas	1.35%	0.66%	1.25%	1.35%	1.01%	0.38%
Ponce	3.39%	2.37%	3.78%	1.56%	5.69%	4.23%
Quebradillas	0.69%	0.75%	0.42%	0.36%	0.58%	0.00%
Rio Grande	0.36%	0.97%	1.27%	1.39%	0.31%	0.37%
Rincon	1.57%	1.40%	3.28%	2.56%	4.38%	7.06%
Sabana Grande	1.16%	0.00%	0.00%	0.00%	0.00%	0.00%
Salinas	1.97%	1.00%	3.42%	2.09%	2.31%	5.20%
San German	1.77%	0.00%	0.00%	0.00%	0.00%	0.00%
San Juan	1.16%	3.91%	6.08%	4.08%	1.56%	2.00%
San Lorenzo	1.73%	0.00%	0.00%	0.00%	0.00%	0.00%
San Sebastian	2.31%	0.00%	0.00%	0.00%	0.00%	0.00%
Santa Isabel	0.89%	1.66%	3.59%	0.00%	0.47%	3.62%
Toa Alta	0.90%	0.00%	0.00%	0.00%	0.00%	0.00%
Toa Baja	0.37%	3.84%	2.73%	3.87%	3.53%	1.47%
Trujillo Alto	0.65%	0.88%	0.00%	0.00%	0.00%	0.00%
Utua	3.74%	0.00%	0.00%	0.00%	0.00%	0.00%
Vega Alta	0.87%	0.13%	0.55%	0.53%	0.00%	0.14%
Vega Baja	1.14%	3.22%	3.81%	4.01%	1.19%	2.31%
Vieques	0.93%	5.63%	6.79%	11.02%	7.12%	3.29%
Villalba	1.20%	0.00%	0.00%	0.00%	0.00%	0.00%
Yabucoa	1.63%	1.64%	1.76%	1.22%	1.83%	0.17%
Yauco	2.22%	0.00%	0.74%	0.00%	0.00%	0.02%

Table 95: Sea Level Rise (4 feet) Hazard Scores and Ranks by Municipio

Municipio	Sea Level Rise (4 Foot) Hazard Score (Log Multiplied)		
	Total Score	Standardized Score (0-1)	Rank of Score (1 – 78)
Loiza	10640.7603	1.0000	1
Cabo Rojo	6317.5315	0.5937	2
Rio Grande	5240.4192	0.4925	3
Arecibo	4612.8528	0.4335	4
Ceiba	3836.8624	0.3606	5
Salinas	3743.8345	0.3518	6
Ponce	3550.8608	0.3337	7
Vieques	3217.7516	0.3024	8
Carolina	3160.8783	0.2971	9
Guayama	2610.2988	0.2453	10
Mayaguez	2599.0903	0.2443	11

Humacao	2527.1449	0.2375	12
Santa Isabel	2439.1991	0.2292	13
Lajas	2326.9730	0.2187	14
Guayanilla	2239.1538	0.2104	15
Culebra	1836.1956	0.1726	16
Barceloneta	1817.1918	0.1708	17
Vega Baja	1714.1996	0.1611	18
Naguabo	1646.0038	0.1547	19
Fajardo	1601.9426	0.1505	20
San Juan	1566.4986	0.1472	21
Toa Baja	1473.7894	0.1385	22
Guanica	1252.0370	0.1177	23
Juana Diaz	995.2300	0.0935	24
Catano	923.4687	0.0868	25
Manati	609.0366	0.0572	26
Patillas	595.4255	0.0560	27
Anasco	519.4689	0.0488	28
Canovanas	491.0325	0.0461	29
Dorado	481.1374	0.0452	30
Isabela	461.7664	0.0434	31
Penuelas	397.7163	0.0374	32
Yabucoa	371.4965	0.0349	33
Luquillo	369.9933	0.0348	34
Arroyo	338.9773	0.0319	35
Aguadilla	318.9439	0.03	36
Aguada	314.8094	0.0296	37
Rincon	298.5289	0.0281	38
Maunabo	104.1538	0.0098	39
Vega Alta	97.9899	0.0092	40
Camuy	86.6050	0.0081	41
Quebradillas	84.5608	0.0079	42
Guaynabo	74.1678	0.007	43
Hatillo	63.8009	0.006	44
Yauco	16.8031	0.0016	45
Adjuntas	0.0000	0.0000	46
Aguas Buenas	0.0000	0.0000	46
Aibonito	0.0000	0.0000	46
Barranquitas	0.0000	0.0000	46
Bayamon	0.2343	0.0000	46
Caguas	0.0000	0.0000	46
Cayey	0.0000	0.0000	46
Ciales	0.0000	0.0000	46

Cidra	0.0000	0.0000	46
Coamo	0.0000	0.0000	46
Comerio	0.0000	0.0000	46
Corozal	0.0000	0.0000	46
Florida	0.0000	0.0000	46
Gurabo	0.0000	0.0000	46
Hormigueros	0.0000	0.0000	46
Jayuya	0.0000	0.0000	46
Juncos	0.0000	0.0000	46
Lares	0.0000	0.0000	46
Las Marias	0.0000	0.0000	46
Las Piedras	0.0000	0.0000	46
Maricao	0.0000	0.0000	46
Moca	0.0000	0.0000	46
Morovis	0.0000	0.0000	46
Naranjito	0.0000	0.0000	46
Orocovis	0.0000	0.0000	46
Sabana Grande	0.0000	0.0000	46
San German	0.0000	0.0000	46
San Lorenzo	0.0000	0.0000	46
San Sebastian	0.0000	0.0000	46
Toa Alta	0.0000	0.0000	46
Trujillo Alto	0.1180	0.0000	46
Utado	0.0000	0.0000	46
Villalba	0.0000	0.0000	46

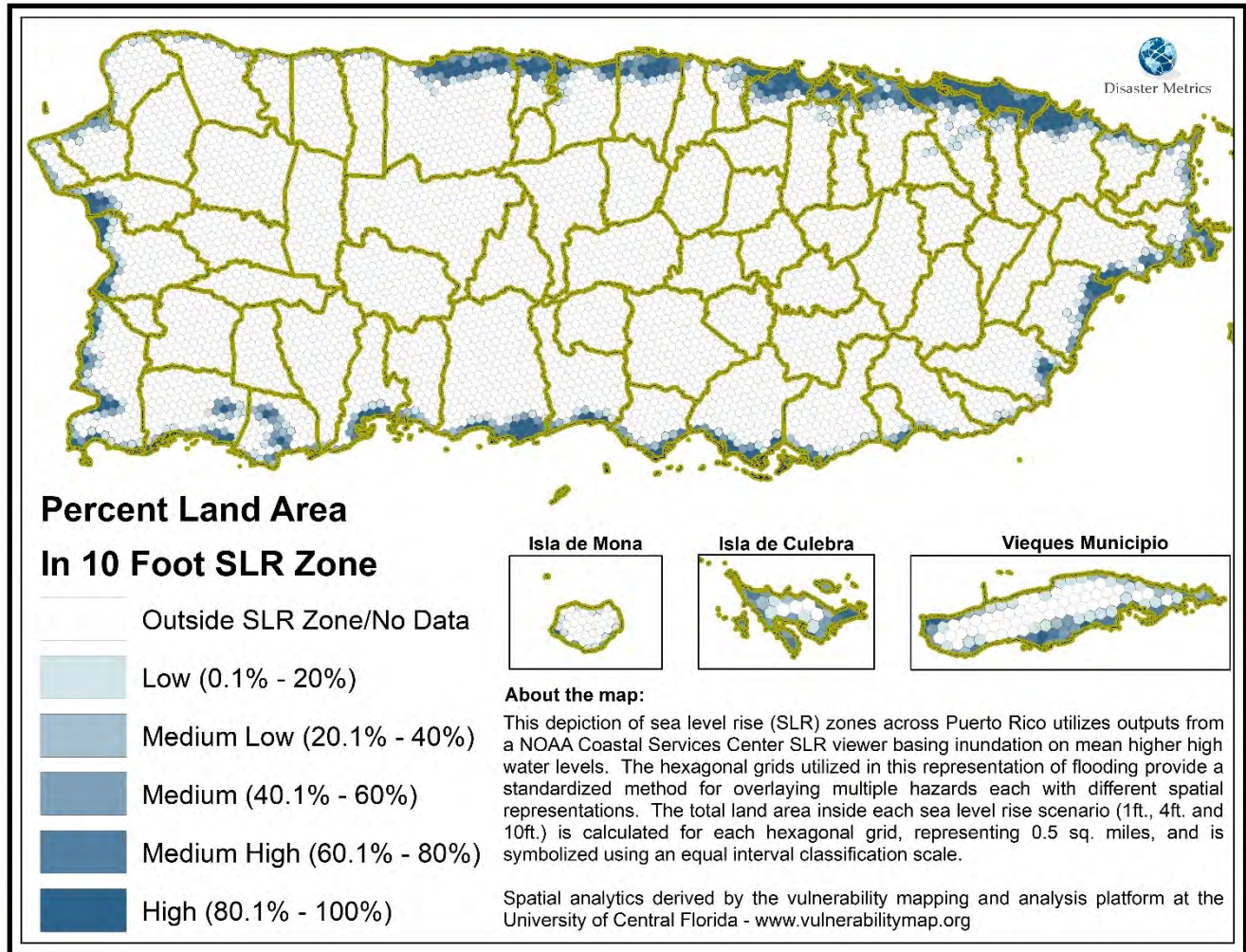


Figure 31: Sea Level Rise (10 feet) Hazard Areas

Table 96: Sea Level Rise (10 feet) by Municipio and Areal Extent

Municipio	Hex Grid Area in Sea Level Rise (10 Feet) Zones (Sq. miles)					
	No SLR/No Date	Low (< 20%)	Medium Low (20.1% - 40%)	Medium (40.1% - 60%)	Medium High (60.1% - 80%)	High (80.1% - 100%)
Adjuntas	67.10					
Aguada	23.15	2.45	1.48	2.91		0.92
Aguadilla	30.62	2.97	1.14	1.07	0.33	0.47
Aguas Buenas	30.10					
Aibonito	31.34					
Anasco	31.25	2.36	1.03	1.30	0.50	3.12
Arecibo	103.56	4.16	3.62	4.73	2.56	8.34
Arroyo	11.53	0.50	1.36		0.54	1.11
Barceloneta	9.43	1.97	1.01	1.33	1.90	3.12
Barranquitas	34.28					
Bayamon	40.47	3.18	0.68		0.17	0.01

Cabo Rojo	45.40	9.01	3.46	4.26	3.06	7.93
Caguas	59.07					
Camuy	43.99	0.60	0.85	0.33	0.51	0.08
Canovanas	26.91	3.66	0.50	0.39	0.90	0.64
Cantano	27.00	7.87	0.50	1.71	1.34	8.89
Carolina		0.31	1.09		0.61	3.08
Cayey	51.96					
Ceiba	17.78	1.69	1.98	2.07	2.69	4.16
Ciales	66.71					
Cidra	36.46					
Coamo	78.03					
Comerio	28.52					
Corozal	42.58					
Culebra	2.00	1.98	1.29	3.39	3.28	1.37
Dorado	13.22	4.25	1.66	0.39	0.79	3.11
Fajardo	21.46	2.45	1.48	2.34	1.38	1.40
Florida	15.22					
Guanica	22.63	4.72	3.51	4.20	2.52	1.42
Guayama	56.50	2.94	1.00	0.77	1.01	3.65
Guayanilla	34.25	1.77	0.86	1.60	1.54	2.97
Guaynabo	25.17	0.82	0.53		0.50	0.74
Gurabo	28.31					
Hatillo	38.85	1.67		0.56	0.60	0.16
Hormigueros	10.88	0.46				
Humacao	31.20	4.38	1.17	1.37	1.98	5.01
Isabela	49.31	2.25	2.21	0.57	0.70	0.37
Jayuya	44.53					
Juana Diaz	53.38	2.07	1.53	0.98	0.00	2.77
Juncos	26.62					
Lajas	46.25	5.62	2.92	1.26	2.31	3.00
Lares	61.64					
Las Marias	46.51					
Las Piedras	33.89					
Loiza	0.35	0.35		1.60	0.89	17.34
Luquillo	19.60	2.00	2.39		0.51	1.37
Manati	34.48	3.97	2.84	1.11	1.28	3.14
Maricao	36.63					
Maunabo	17.64	1.98	0.33	0.64	0.11	0.38
Mayaguez	56.70	9.40	1.94	1.16	1.45	7.32
Moca	50.37					
Morovis	38.93					
Naguabo	41.45	3.43	0.41	0.99	2.63	2.96

Naranjito	27.75					
Orocovis	63.78					
Patillas	43.52	0.51	1.39		1.21	0.58
Penuelas	40.47	0.50	1.74	0.47	0.51	1.07
Ponce	100.50	2.93	1.54	2.82	1.41	7.78
Quebradillas	20.17	2.19	0.25		0.53	0.00
Rio Grande	9.48	1.47	1.86	0.65	0.51	0.42
Rincon	45.91	2.32	1.06	1.50	1.50	8.52
Sabana Grande	35.84					
Salinas	58.14	2.96		2.14	1.16	5.65
San German	54.51					
San Juan	33.51	3.15	2.02	2.49	4.60	3.76
San Lorenzo	53.21					
San Sebastian	71.22					
Santa Isabel	26.36	1.00	2.36	1.20	0.99	2.67
Toa Alta	27.56					
Toa Baja	7.66	2.73	2.02	1.00	2.19	8.21
Trujillo Alto	20.09	1.29				
Utua	115.07					
Vega Alta	26.22	0.07	0.50	0.49	0.36	0.09
Vega Baja	31.04	4.01	0.90	2.66	3.11	4.91
Vieques	24.00	11.76	3.65	4.26	6.24	3.27
Villalba	37.04					
Yabucoa	48.14	2.49	1.47	0.70	1.50	1.11
Yauco	68.14	0.23	0.43			0.02
Grand Total	2984.50	136.88	65.95	63.43	64.44	148.43

Table 97: Percent of (Municipio) Hexagonal Area by Sea Level Rise (10 feet) per Municipio

Municipio	Sea Level Rise (10 Feet) Percent Area by Total (Municipio) Land Area					
	No SLR/No Data	Low (< 20%)	Medium Low (20.1% - 40%)	Medium (40.1% - 60%)	Medium High (60.1% - 80%)	High (80.1% - 100%)
Adjuntas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Aguada	74.86%	7.93%	4.80%	9.42%	0.00%	2.98%
Aguadilla	83.65%	8.12%	3.12%	2.92%	0.90%	1.29%
Aguas Buenas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Aibonito	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Anasco	78.99%	5.96%	2.61%	3.28%	1.26%	7.89%
Arecibo	81.56%	3.27%	2.85%	3.73%	2.02%	6.57%
Arroyo	76.64%	3.32%	9.02%	0.00%	3.62%	7.40%
Barceloneta	50.27%	10.49%	5.38%	7.10%	10.13%	16.63%
Barranquitas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Bayamon	90.92%	7.14%	1.54%	0.00%	0.38%	0.03%
Cabo Rojo	62.09%	12.32%	4.74%	5.83%	4.19%	10.84%
Caguas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Camuy	94.87%	1.30%	1.84%	0.71%	1.11%	0.17%
Canovanas	81.53%	11.10%	1.51%	1.17%	2.74%	1.95%
Cantano	57.07%	16.65%	1.05%	3.61%	2.83%	18.79%
Carolina	0.00%	6.05%	21.51%	0.00%	11.94%	60.50%
Cayey	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Ceiba	58.55%	5.56%	6.53%	6.81%	8.85%	13.70%
Ciales	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Cidra	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Coamo	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Comerio	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Corozal	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Culebra	15.03%	14.88%	9.66%	25.51%	24.65%	10.28%
Dorado	56.45%	18.16%	7.08%	1.66%	3.35%	13.30%
Fajardo	70.33%	8.04%	4.86%	7.67%	4.51%	4.59%
Florida	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Guanica	58.01%	12.10%	8.99%	10.78%	6.47%	3.65%
Guayama	85.78%	4.46%	1.51%	1.17%	1.54%	5.54%
Guayanilla	79.67%	4.12%	2.01%	3.72%	3.58%	6.91%
Guaynabo	90.67%	2.94%	1.91%	0.00%	1.80%	2.68%
Gurabo	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Hatillo	92.85%	3.99%	0.00%	1.34%	1.43%	0.39%
Hormigueros	95.94%	4.06%	0.00%	0.00%	0.00%	0.00%
Humacao	69.17%	9.72%	2.59%	3.04%	4.38%	11.10%
Isabela	89.00%	4.06%	3.98%	1.03%	1.26%	0.67%
Jayuya	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Juana Diaz	87.89%	3.40%	2.53%	1.61%	0.00%	4.56%
Juncos	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lajas	75.36%	9.17%	4.75%	2.05%	3.77%	4.90%
Lares	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Marias	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Piedras	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Loiza	1.70%	1.71%	0.00%	7.77%	4.36%	84.46%
Luquillo	75.78%	7.73%	9.22%	0.00%	1.98%	5.28%
Manati	73.63%	8.48%	6.07%	2.38%	2.73%	6.71%
Maricao	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Maunabo	83.66%	9.41%	1.56%	3.04%	0.51%	1.81%
Mayaguez	72.72%	12.05%	2.49%	1.49%	1.86%	9.39%
Moca	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Morovis	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Naguabo	79.90%	6.61%	0.79%	1.92%	5.08%	5.70%
Naranjito	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Orocovis	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Patillas	92.17%	1.09%	2.94%	0.00%	2.57%	1.22%
Penuelas	90.43%	1.12%	3.88%	1.04%	1.14%	2.39%
Ponce	85.91%	2.51%	1.32%	2.41%	1.21%	6.65%
Quebradillas	87.17%	9.46%	1.08%	0.00%	2.28%	0.01%
Rio Grande	65.86%	10.24%	12.89%	4.54%	3.58%	2.90%
Rincon	75.50%	3.82%	1.74%	2.47%	2.47%	14.00%
Sabana Grande	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Salinas	82.99%	4.23%	0.00%	3.06%	1.66%	8.07%
San German	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
San Juan	67.66%	6.35%	4.08%	5.03%	9.29%	7.58%
San Lorenzo	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
San Sebastian	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Santa Isabel	76.24%	2.89%	6.82%	3.46%	2.88%	7.71%
Toa Alta	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Toa Baja	32.17%	11.46%	8.47%	4.20%	9.22%	34.48%
Trujillo Alto	93.98%	6.02%	0.00%	0.00%	0.00%	0.00%
Utua	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Vega Alta	94.51%	0.26%	1.80%	1.78%	1.31%	0.34%
Vega Baja	66.55%	8.61%	1.93%	5.71%	6.68%	10.52%
Vieques	45.13%	22.12%	6.87%	8.01%	11.73%	6.15%
Villalba	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Yabucoa	86.88%	4.49%	2.65%	1.27%	2.70%	2.01%
Yauco	99.01%	0.33%	0.63%	0.00%	0.00%	0.02%

Table 98: Percent of (Island) Hexagonal Area by Sea Level Rise (10 feet) per Municipio

Municipio	Sea Level Rise (10 Feet) Percent Area by Total (Island) Land Area					
	No SLR/No Data	Low (< 20%)	Medium Low (20.1% - 40%)	Medium (40.1% - 60%)	Medium High (60.1% - 80%)	High (80.1% - 100%)
Adjuntas	2.25%	0.00%	0.00%	0.00%	0.00%	0.00%
Aguada	0.78%	1.79%	2.25%	4.59%	0.00%	0.62%
Aguadilla	1.03%	2.17%	1.73%	1.69%	0.51%	0.32%
Aguas Buenas	1.01%	0.00%	0.00%	0.00%	0.00%	0.00%
Aibonito	1.05%	0.00%	0.00%	0.00%	0.00%	0.00%
Anasco	1.05%	1.72%	1.57%	2.04%	0.78%	2.10%
Arecibo	3.47%	3.04%	5.50%	7.46%	3.98%	5.62%
Arroyo	0.39%	0.37%	2.06%	0.00%	0.84%	0.75%
Barceloneta	0.32%	1.44%	1.53%	2.10%	2.95%	2.10%
Barranquitas	1.15%	0.00%	0.00%	0.00%	0.00%	0.00%

Bayamon	1.36%	2.32%	1.04%	0.00%	0.26%	0.01%
Cabo Rojo	1.52%	6.58%	5.25%	6.72%	4.75%	5.34%
Caguas	1.98%	0.00%	0.00%	0.00%	0.00%	0.00%
Camuy	1.47%	0.44%	1.29%	0.52%	0.80%	0.05%
Canovanas	0.90%	2.68%	0.76%	0.61%	1.40%	0.43%
Cantano	0.90%	5.75%	0.75%	2.69%	2.08%	5.99%
Carolina	0.00%	0.22%	1.66%	0.00%	0.94%	2.07%
Cayey	1.74%	0.00%	0.00%	0.00%	0.00%	0.00%
Ceiba	0.60%	1.23%	3.01%	3.26%	4.17%	2.80%
Ciales	2.24%	0.00%	0.00%	0.00%	0.00%	0.00%
Cidra	1.22%	0.00%	0.00%	0.00%	0.00%	0.00%
Coamo	2.61%	0.00%	0.00%	0.00%	0.00%	0.00%
Comerio	0.96%	0.00%	0.00%	0.00%	0.00%	0.00%
Corozal	1.43%	0.00%	0.00%	0.00%	0.00%	0.00%
Culebra	0.07%	1.45%	1.95%	5.35%	5.09%	0.92%
Dorado	0.44%	3.11%	2.51%	0.61%	1.22%	2.10%
Fajardo	0.72%	1.79%	2.25%	3.69%	2.14%	0.94%
Florida	0.51%	0.00%	0.00%	0.00%	0.00%	0.00%
Guanica	0.76%	3.45%	5.32%	6.63%	3.92%	0.96%
Guayama	1.89%	2.15%	1.51%	1.21%	1.57%	2.46%
Guayanilla	1.15%	1.29%	1.31%	2.52%	2.39%	2.00%
Guaynabo	0.84%	0.60%	0.80%	0.00%	0.78%	0.50%
Gurabo	0.95%	0.00%	0.00%	0.00%	0.00%	0.00%
Hatillo	1.30%	1.22%	0.00%	0.89%	0.93%	0.11%
Hormigueros	0.36%	0.34%	0.00%	0.00%	0.00%	0.00%
Humacao	1.05%	3.20%	1.77%	2.16%	3.07%	3.37%
Isabela	1.65%	1.64%	3.34%	0.90%	1.08%	0.25%
Jayuya	1.49%	0.00%	0.00%	0.00%	0.00%	0.00%
Juana Diaz	1.79%	1.51%	2.33%	1.54%	0.00%	1.87%
Juncos	0.89%	0.00%	0.00%	0.00%	0.00%	0.00%
Lajas	1.55%	4.11%	4.42%	1.99%	3.59%	2.02%
Lares	2.07%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Marias	1.56%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Piedras	1.14%	0.00%	0.00%	0.00%	0.00%	0.00%
Loiza	0.01%	0.26%	0.00%	2.52%	1.39%	11.68%
Luquillo	0.66%	1.46%	3.62%	0.00%	0.79%	0.92%
Manati	1.16%	2.90%	4.31%	1.75%	1.98%	2.12%
Maricao	1.23%	0.00%	0.00%	0.00%	0.00%	0.00%
Maunabo	0.59%	1.45%	0.50%	1.01%	0.17%	0.26%
Mayaguez	1.90%	6.87%	2.94%	1.83%	2.25%	4.93%
Moca	1.69%	0.00%	0.00%	0.00%	0.00%	0.00%
Morovis	1.30%	0.00%	0.00%	0.00%	0.00%	0.00%

Naguabo	1.39%	2.51%	0.62%	1.57%	4.09%	1.99%
Naranjito	0.93%	0.00%	0.00%	0.00%	0.00%	0.00%
Orocovis	2.14%	0.00%	0.00%	0.00%	0.00%	0.00%
Patillas	1.46%	0.38%	2.10%	0.00%	1.88%	0.39%
Penuelas	1.36%	0.37%	2.63%	0.74%	0.79%	0.72%
Ponce	3.37%	2.14%	2.33%	4.45%	2.19%	5.24%
Quebradillas	0.68%	1.60%	0.38%	0.00%	0.82%	0.00%
Rio Grande	0.32%	1.08%	2.81%	1.03%	0.80%	0.28%
Rincon	1.54%	1.70%	1.60%	2.36%	2.33%	5.74%
Sabana Grande	1.20%	0.00%	0.00%	0.00%	0.00%	0.00%
Salinas	1.95%	2.16%	0.00%	3.38%	1.80%	3.81%
San German	1.83%	0.00%	0.00%	0.00%	0.00%	0.00%
San Juan	1.12%	2.30%	3.06%	3.93%	7.14%	2.53%
San Lorenzo	1.78%	0.00%	0.00%	0.00%	0.00%	0.00%
San Sebastian	2.39%	0.00%	0.00%	0.00%	0.00%	0.00%
Santa Isabel	0.88%	0.73%	3.57%	1.89%	1.54%	1.80%
Toa Alta	0.92%	0.00%	0.00%	0.00%	0.00%	0.00%
Toa Baja	0.26%	1.99%	3.06%	1.58%	3.40%	5.53%
Trujillo Alto	0.67%	0.94%	0.00%	0.00%	0.00%	0.00%
Utua	3.86%	0.00%	0.00%	0.00%	0.00%	0.00%
Vega Alta	0.88%	0.05%	0.76%	0.78%	0.56%	0.06%
Vega Baja	1.04%	2.93%	1.37%	4.20%	4.83%	3.31%
Vieques	0.80%	8.59%	5.54%	6.71%	9.68%	2.20%
Villalba	1.24%	0.00%	0.00%	0.00%	0.00%	0.00%
Yabucoa	1.61%	1.82%	2.23%	1.11%	2.32%	0.75%
Yauco	2.28%	0.17%	0.66%	0.00%	0.00%	0.01%

Table 99: Sea Level Rise (10 feet) Hazard Scores and Ranks by Municipio

Municipio	Sea Level Rise (10 Feet) Hazard Score (Log Multiplied)		
	Total Score	Standardized Score (0-1)	Rank of Score (1 – 78)
Loiza	10177.1975	1.0000	1
Carolina	5379.1416	0.5285	2
Arecibo	5332.6982	0.5240	3
Rio Grande	5185.6525	0.5095	4
Cabo Rojo	5161.2298	0.5071	5
Toa Baja	5111.4621	0.5022	6
Ponce	4775.2550	0.4692	7
Mayaguez	4484.8948	0.4407	8
Salinas	3489.7799	0.3429	9
Vega Baja	3388.8586	0.3330	10
Humacao	3236.0426	0.3180	11
Vieques	2987.0529	0.2935	12

San Juan	2961.7929	0.2910	13
Ceiba	2878.8438	0.2829	14
Guayama	2286.9289	0.2247	15
Naguabo	2151.2555	0.2114	16
Lajas	2138.2723	0.2101	17
Barceloneta	2135.0209	0.2098	18
Manati	2049.3914	0.2014	19
Guayanilla	1996.6959	0.1962	20
Dorado	1934.7518	0.1901	21
Anasco	1910.8489	0.1878	22
Catano	1873.8014	0.1841	23
Santa Isabel	1728.1665	0.1698	24
Juana Diaz	1622.0071	0.1594	25
Culebra	1390.2438	0.1366	26
Guanica	1323.9798	0.1301	27
Fajardo	1082.0722	0.1063	28
Yabucoa	901.1467	0.0885	29
Luquillo	876.4141	0.0861	30
Arroyo	733.0881	0.0720	31
Penuelas	713.3990	0.0701	32
Aguada	597.7969	0.0587	33
Patillas	532.0206	0.0523	34
Canovanas	526.2047	0.0517	35
Guaynabo	510.7560	0.0502	36
Aguadilla	350.7395	0.0345	37
Isabela	344.4149	0.0338	38
Rincon	341.7857	0.0336	39
Maunabo	252.3595	0.0248	40
Hatillo	201.3805	0.0198	41
Camuy	138.1980	0.0136	42
Vega Alta	124.0816	0.0122	43
Quebradillas	87.1037	0.0086	44
Bayamon	35.7280	0.0035	45
Yauco	10.4031	0.0010	46
Adjuntas	0.0000	0.0000	47
Aguas Buenas	0.0000	0.0000	47
Aibonito	0.0000	0.0000	47
Barranquitas	0.0000	0.0000	47
Caguas	0.0000	0.0000	47
Cayey	0.0000	0.0000	47
Ciales	0.0000	0.0000	47
Cidra	0.0000	0.0000	47

Coamo	0.0000	0.0000	47
Comerio	0.0000	0.0000	47
Corozal	0.0000	0.0000	47
Florida	0.0000	0.0000	47
Gurabo	0.0000	0.0000	47
Hormigueros	0.0391	0.0000	47
Jayuya	0.0000	0.0000	47
Juncos	0.0000	0.0000	47
Lares	0.0000	0.0000	47
Las Marias	0.0000	0.0000	47
Las Piedras	0.0000	0.0000	47
Maricao	0.0000	0.0000	47
Moca	0.0000	0.0000	47
Morovis	0.0000	0.0000	47
Naranjito	0.0000	0.0000	47
Orocovis	0.0000	0.0000	47
Sabana Grande	0.0000	0.0000	47
San German	0.0000	0.0000	47
San Lorenzo	0.0000	0.0000	47
San Sebastian	0.0000	0.0000	47
Toa Alta	0.0000	0.0000	47
Trujillo Alto	0.1095	0.0000	47
Utua	0.0000	0.0000	47
Villalba	0.0000	0.0000	47

Vulnerability

Understanding which populations and what assets are likely to be impacted by hazard events is critical for developing sound mitigation planning activities and projects. Here, vulnerability is defined by combining three different indicators: critical infrastructure assets provide a representation of what is at risk; socially vulnerable areas provide an idea of who has a lower capacity to absorb shocks and stresses, and total population supports a utilitarian approach to serving the greatest number of peoples. Combining these three vulnerability indicators into a single measure enables an accounting of all three characteristics in an empirical way. Vulnerability was determined by developing a GIS inventory of critical infrastructure assets⁴⁵, population of people, and population of socially vulnerable populations. Critical infrastructure assets are transportation facilities, communication facilities, water and wastewater facilities, and power facilities. These facilities are those that all other infrastructure lifelines are dependent on. Social vulnerable populations were derived from the Social Vulnerability Index first developed by Cutter (2003)⁴⁶ and later refined by scholars at the University of Central Florida⁴⁷. Understanding where populations reside who have a lower ability to prepare for, respond to, and recover from disaster events can help decision makers distribute scarce resources before, during, or after disasters. Population density was derived from the HUD LMISD at the block group level. Each of the three components of vulnerability used here are summarized below.

Critical Infrastructure

Critical infrastructure assets (Table 100) across Puerto Rico were assessed using FEMA's Lifeline⁴⁸ with the understanding that

- Lifelines enable the continuous operation of critical government and business functions and is essential to human health and safety or economic security.
- Lifelines are the most fundamental services in the community that, when stabilized, enable all other aspects of society to function.
- FEMA has developed a construct for objectives-based response that prioritizes the rapid stabilization of Community Lifelines after a disaster.
- The integrated network of assets, services, and capabilities that provide lifeline services are used day-to-day to support the recurring needs of the community and enable all other aspects of society to function.

⁴⁵ <https://www.fema.gov/lifelines>

⁴⁶ <https://onlinelibrary.wiley.com/doi/abs/10.1111/1540-6237.8402002>

⁴⁷ www.vulnerabilitymap.org

⁴⁸ <https://www.fema.gov/lifelines>

- When disrupted, decisive intervention (e.g., rapid re-establishment or employment of contingency response solutions) is required to stabilize the incident.

Table 100: Critical Infrastructure Included in Puerto Rico’s Hazard Risk Assessment

Critical Infrastructure Asset	Data Source	URL	Date Accessed
Water/Wastewater Lines	PRASA		2/25/2020
Water/Wastewater Facilities	PRASA		2/25/2020
Power Plants	Homeland Infrastructure Foundation-Level Data (HIFLD)	https://hifld-geoplatform.opendata.arcgis.com/	4/16/2020
Electric Power Transmission Lines	Homeland Infrastructure Foundation-Level Data (HIFLD)	https://hifld-geoplatform.opendata.arcgis.com/	4/16/2020
PR Roads	United State Census Bureau	https://www.census.gov/cgi-bin/geo/shapefiles/index.php	4/16/2020
Major Ports	Homeland Infrastructure Foundation-Level Data (HIFLD)	https://hifld-geoplatform.opendata.arcgis.com/	4/19/2020
Ports	Homeland Infrastructure Foundation-Level Data (HIFLD)	https://hifld-geoplatform.opendata.arcgis.com/	4/19/2020
Airports	Homeland Infrastructure Foundation-Level Data (HIFLD)	https://hifld-geoplatform.opendata.arcgis.com/	4/19/2020
Broadband Radio and Educational Broadband Radio	Homeland Infrastructure Foundation-Level Data (HIFLD)	https://hifld-geoplatform.opendata.arcgis.com/	4/22/2020
FM Radio Towers	Homeland Infrastructure Foundation-Level Data (HIFLD)	https://hifld-geoplatform.opendata.arcgis.com/	4/22/2020
Land Mobile Radio Stations	Homeland Infrastructure Foundation-Level Data (HIFLD)	https://hifld-geoplatform.opendata.arcgis.com/	4/22/2020
AM Radio Transmitters	Homeland Infrastructure Foundation-Level Data (HIFLD)	https://hifld-geoplatform.opendata.arcgis.com/	4/22/2020
Cellular Radio Towers	Homeland Infrastructure Foundation-Level Data (HIFLD)	https://hifld-geoplatform.opendata.arcgis.com/	4/22/2020
Microwave Radio Transmitters	Homeland Infrastructure Foundation-Level Data (HIFLD)	https://hifld-geoplatform.opendata.arcgis.com/	4/22/2020

Critical Infrastructure Density

Critical infrastructure locations are captured and mapped using either point features (individual locations) or line features (sets of point features) depending on the infrastructure asset. For example, electric generation facilities would be represented by a point while electrical transmission lines would be represented as line features inside a GIS system. For this assessment, line feature classes representing critical infrastructure were converted to point feature classes using the ESRI ArcGIS Pro Generate Points Along Lines tool generating a point at each end point and every 200 meters along the line feature. Critical infrastructure point data and point data generated from the line features was then merged to create one complete point feature representation of critical infrastructure. This point data was then geoprocessed with the ESRI ArcGIS Pro Summarize Within tool to generate a count of points within each .5-mile hex grid. Critical infrastructure counts were then classified using an equal interval classifications scheme and mapped using the same output hex grid as the hazard threat maps (Figure 32).

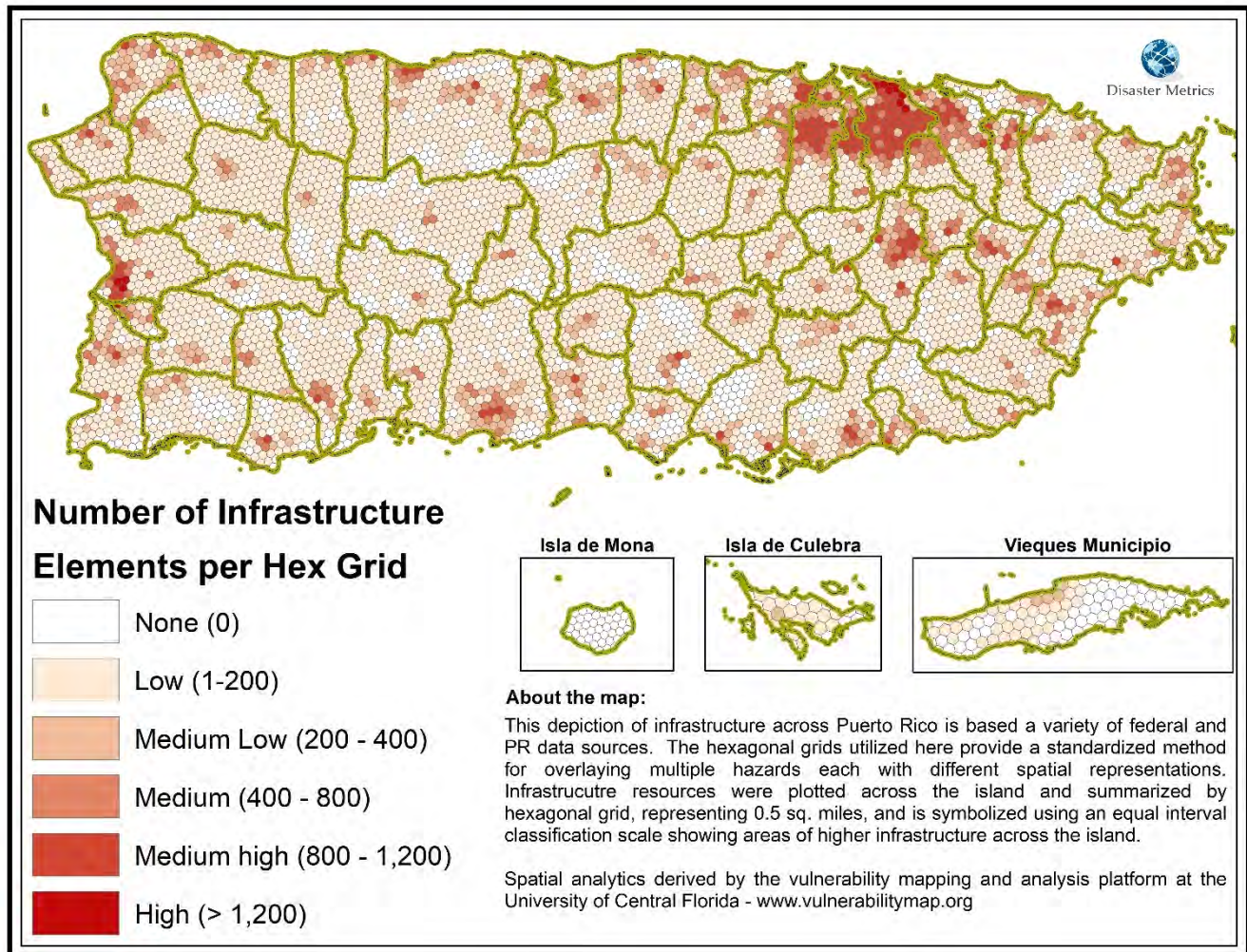


Figure 32: Puerto Rico's Critical Infrastructure Elements gathered using FEMA's lifeline guidance.

Social Vulnerability

Social vulnerability, a concept focused on understanding an area's capacity to prepare for, respond to, and rebound from disaster events⁴⁹, has a long conceptual and theoretical history in social and disaster science fields.⁵⁰ Socially vulnerable populations have fewer resources to aid in preparation for disasters, often bear the brunt of disaster impacts, and take longer to bounce back from disaster events. Empirical measures of social vulnerability enable decision makers and emergency managers to understand where vulnerable populations reside and how that vulnerability is manifest across a landscape. Here, 29 indicators of social vulnerability, collected from www.vulnerabilitymap.org, were used to create a SoVI for Puerto Rico. SoVI scores were categorized from (0 – no data to 5 – high social vulnerability) using a standard deviation classification scheme (Figure 33).

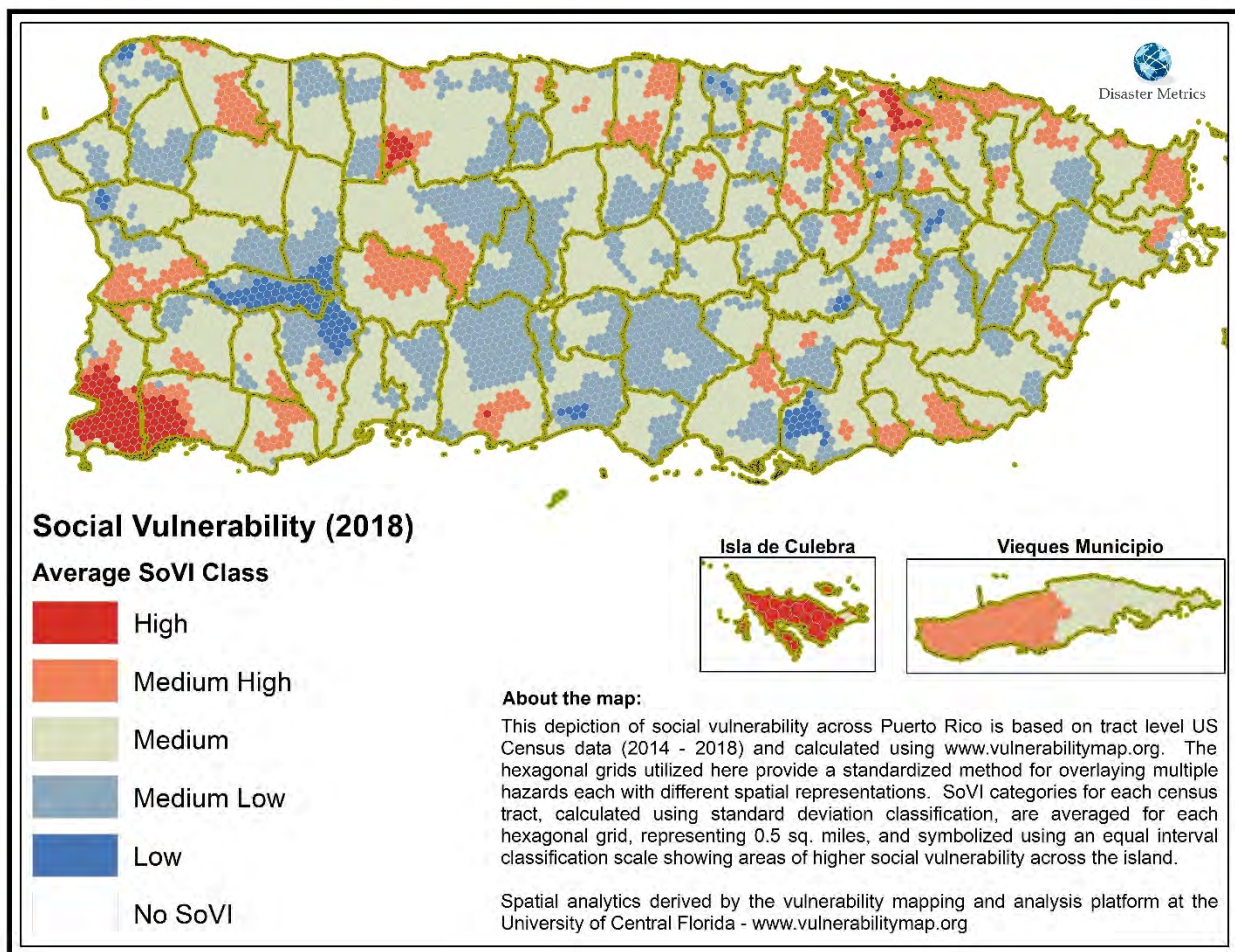


Figure 33: Puerto Rico's Social Vulnerability Index⁵¹

⁴⁹ <https://doi.org/10.1177/0002716205285515>

⁵⁰ <https://unu.edu/publications/books/measuring-vulnerability-to-natural-hazards-towards-disaster-resilient-societies-second-edition.html#overview>

⁵¹ Created from www.vulnerabilitymap.org

Population Density

Population data collected from the American Community Survey products developed for HUD's LMI block group dataset the block group level.⁵² This population data was geo-processed with the ESRI ArcGIS Pro Create Random Points tool to randomly distribute population (Low- Moderate Universe). Like critical infrastructure, this population data was geo-processed with the ESRI ArcGIS Pro Summarize Within tool to generate a count of points within each .5-mile hex grid. Population per hex grid was classified on a quasi-exponential classification scale showing areas with higher populations across Puerto Rico (Figure 34).

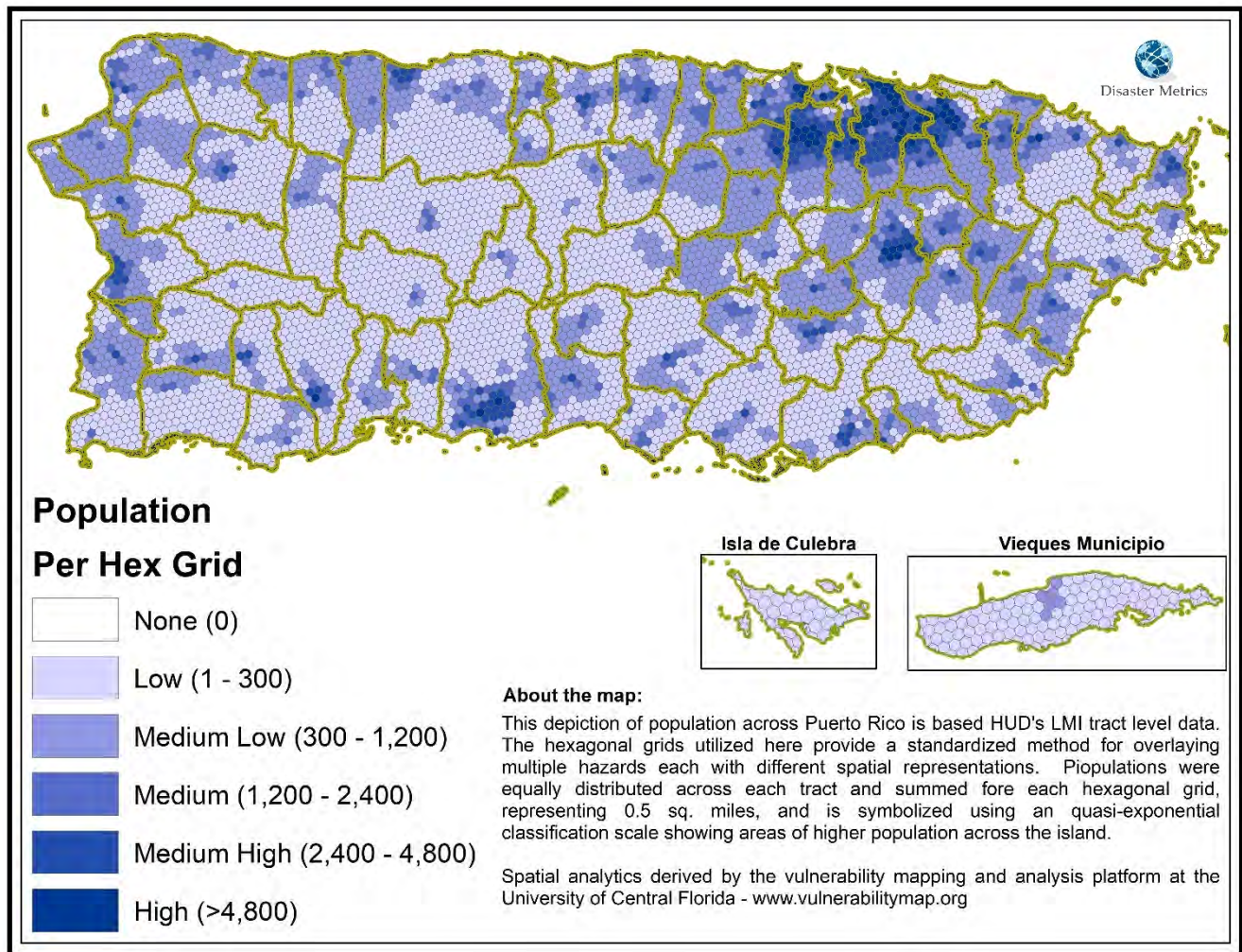


Figure 34: Puerto Rico's Population Distribution

⁵² <https://www.hudexchange.info/programs/acs-low-mod-summary-data/acs-low-mod-summary-data-block-groups-places/>

Each vulnerability variable (Critical Infrastructure Density, Social Vulnerability, and Population Density) was classified from zero (0) to five (5). The variables were then summed and divided by three (3) to develop a composite vulnerability score from zero (0) to five (5) (Equation 1 and Figure 35).

Equation 1: Vulnerability Calculation

$$VUL = \frac{(SoVI) + (INF) + (POP)}{3}$$

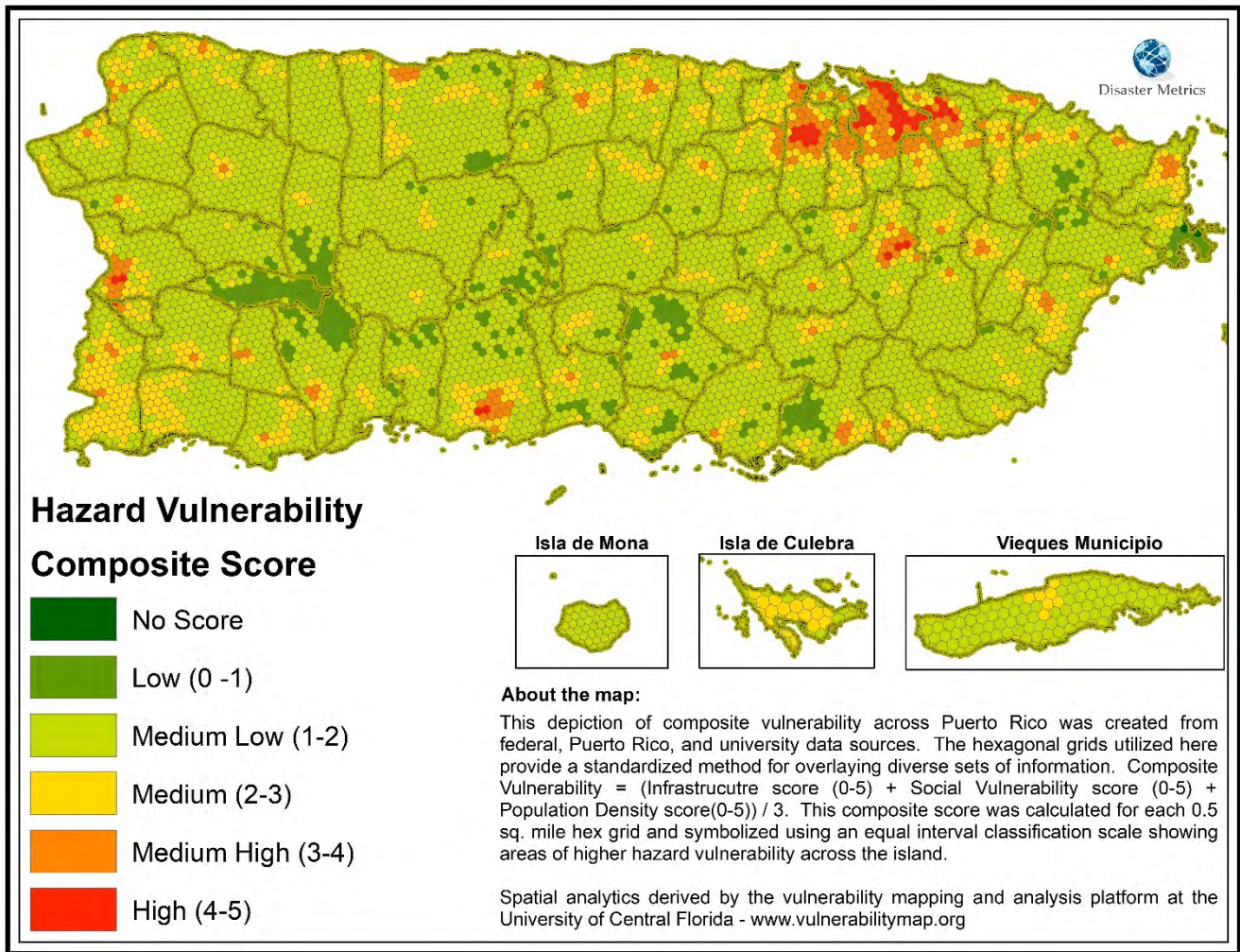


Figure 35: Puerto Rico's Composite Hazard Vulnerability

Severity of Consequences

Each single hazard event and event type (flooding, hurricane, etc.) has a different severity of consequence. Creating a universal understanding of hazard risk for Puerto Rico required creation of a robust accounting of consequences accounting for historical losses and also forward looking and able to reflect possible climate sensitivities, current high priority hazards, and those likely to cause continued losses if not mitigated. For this assessment, Severity of Consequences is calculated (Equation 2) using equal parts Historical Consequence, Climate Sensitivity, a measure of probability vs consequence, and a measure of future impacts (or high priority hazards for Puerto Rico) derived from Puerto Rico’s current Hazard Mitigation Plan.⁵³

Equation 2: Severity of Consequences Calculation

$$\begin{aligned} CON_{HAZ_n} = & (HISTORIC\ CONSEQUENCE) \\ & + (CLIMATE\ SENSITIVE) \\ & + (PROBABILITY\ CONSEQUENCE) \\ & + (FUTURE\ CONSEQUENCE) \end{aligned}$$

HAZ= Flood, Earthquake, Landslide, Category-1 Storm Surge, Category-2 Storm Surge, Category-3 Storm Surge, Category-4 Storm Surge, Category-5 Storm Surge, Severe Storm, Tsunami, Drought, Wind, Fog, Hail, High Temperature, Lightning, Tornado, Wildfire, Sea Level Rise 1-foot, Sea Level Rise 4-foot, Sea Level Rise 10-foot, Liquefaction, Human Hazard, Hurricane Force Wind;

Historic Consequence

Hazard consequence is the sum of historical frequency, economic impacts, fatalities, and injuries from past disaster events.

Equation 3: Historical Consequence Calculation

$$\begin{aligned} HAZCON_{HAZ_n} = & \textit{Historical Frequency Score} \\ & + \textit{Historical Economic Impacts Score} \\ & + \textit{Historical Fatality Score} \\ & + \textit{Historical Injury Score} \end{aligned}$$

Where:

⁵³ Puerto Rico Hazard Mitigation Plan - <https://recovery.pr/en/document-library>

Historical Frequency Score - a Min/Max standardized (0-1) indicator of recorded⁵⁴ frequency of occurrence for past loss causing Hazard (*HAZ*) events.

Historical Economic Impacts Score - a Min/Max standardized (0-1) indicator of recorded damages from past loss causing Hazard (*HAZ*) events.

Historical Fatality Score - a Min/Max standardized (0-1) indicator of recorded fatalities from past loss causing Hazard (*HAZ*) events.

Historical Injury Score (Table 101) - a Min/Max standardized (0-1) indicator of recorded injuries from past loss causing Hazard (*HAZ*) events.

Table 101: Historical Consequence Scores by Hazard

Hazard	Historical Frequency Score (0-1)	Historical Consequence Score (0-1)	Historical Fatality Score (0-1)	Historical Injury Score (0-1)	Sum of Historical Scores (0-4)
Flood	0.502331	1	1	0.093023	2.297677
Coastal Flood and SLR	0.023103	0.000276	0.314286	0.395349	0.523787
Hurricane (Surge and wind)	0.02925	0.174968	0.057143	0.023256	0.258363
Earthquake and Liquefaction	0.002755	0.149326	0	0	0.150704
Landslide	0.072064	0.000311	0.042857	0.093023	0.125712
Drought	0.004875	0.000326	0	0	0.002764
Tsunami	0	0	0	0	0
Human Hazards	0.091988	0.00298	0.314286	1	0.86326
Wildfire	0.009326	0.000547	0	0	0.00521
Severe Storm	0.204324	0.001342	0.185714	0.511628	0.545032
Fog	1	0	0.028571	0	0.528571
Lightning	0.005935	2.66E-05	0.085714	0.139535	0.158476
Tornado	0.028826	8.72E-05	0	0	0.0145
Wind	0.008266	2.26E-05	0	0.046512	0.027412
Hail	0.013141	2.71E-05	0	0.023256	0.018226
Heat	0.017804	0	0	0	0.008902

⁵⁴ <https://www.ncdc.noaa.gov/stormevents/>

Climate Sensitivity

Each hazard was classified (0 or 1) on its climate sensitivity, or its connection to current and future weather. If a hazard’s root cause is meteorological (floods, hurricanes, heat, hail, etc.) it is climate sensitive and scored with a one (1). If a hazard is geophysical (earthquake, tsunami, etc.) is not climate sensitive and is scored with a zero (0).

Probability/Consequence

Generally, hazards fall into two specific types in terms of probability and consequence. Low probability/high consequence disasters (Earthquake, tsunami) have a generally low frequency of occurrence with a much higher consequence when they do occur. Conversely, high probability/low consequence events occur more frequently but cause less damage and impact on society when they do. Each hazard event type was appraised on its probability/consequence and scored between (Low - .05 and High – 1).

Future Consequence

Each hazard included in the assessment has either impacted Puerto Rico in the past or has the potential to cause future impacts. Future consequence scores each hazard on its potential to be an impactful hazard in the future. Future consequence scores range from (Low - .05 and High – 1) and are derived from review of Puerto Rico’s Hazard Mitigation Plan⁵⁵. Hazards identified as “high priority” in the plan were scored high future consequence and hazards not in the plan (heat, tornado, severe storm, etc.) were scored lower on future consequence (.05 or .1).

Resulting Severity of Consequences (SOC) score

Applying (Equation 2) to historical consequences, climate sensitivity, probability/consequence, and future consequences results in a standardized value for severity of consequences (SOC0 for each hazard analyzed in this assessment. In this case, flooding hazard poses the highest risk and heat hazard poses the lowest risk across Puerto Rico (Table 102).

Table 102: Severity of Consequence Scores by Hazard

Hazard	Sum of Historical Scores (0-4)	Climate Sensitive (0-1)	Probability / Consequence (0-1)	Future Consequence (0-1)	Composite SOC Score (0-7)	Standardized SOC Score (0-1)	Rank	Severity of Consequences Score (0 – 5)
Flood	2.298	1.000	0.500	1.000	4.798	1.000	1	5.000
Coastal Flood and SLR	0.524	1.000	0.500	1.000	3.024	0.506	2	2.529

⁵⁵ Puerto Rico Hazard Mitigation Plan - <https://recovery.pr/en/document-library>

Hurricane Storm Surge and Wind	0.258	1.000	0.750	1.000	3.008	0.501	3	2.507
Earthquake and Liquefaction	0.151	0.000	1.000	1.000	2.151	0.262	4	1.312
Landslide	0.126	1.000	0.500	0.500	2.126	0.255	5	1.277
Drought	0.003	1.000	0.500	0.500	2.003	0.221	6	1.106
Tsunami	0.000	0.000	1.000	1.000	2.000	0.220	7	1.102
Human Hazards	0.863	0.000	0.500	0.500	1.863	0.182	8	0.912
Wildfire	0.005	1.000	0.250	0.500	1.755	0.152	9	0.761
Severe Storm	0.545	1.000	0.100	0.100	1.745	0.149	10	0.747
Fog	0.529	1.000	0.100	0.100	1.729	0.145	11	0.724
Lightning	0.158	1.000	0.250	0.100	1.508	0.083	12	0.417
Tornado	0.015	1.000	0.250	0.100	1.365	0.043	13	0.217
Wind	0.027	1.000	0.100	0.100	1.227	0.005	14	0.026
Hail	0.018	1.000	0.100	0.100	1.218	0.003	15	0.013
Heat	0.009	1.000	0.100	0.100	1.209	0.000	16	0.001

Risk

The risk from hazard for each ½ mile hex grid was derived from the product of Vulnerability, Hazard, and Severity of Consequence (Equation 4).

Equation 4: Hazard Risk Calculation

$$RISK_{HAZ_n} = (VUL)(HAZ_n)(CON_{HAZ_n})$$

Risk scores for each hazard were created using this method and the most risky hazards (by hex grid) were mapped to identify trends in risk across Puerto Rico (Figure 36).

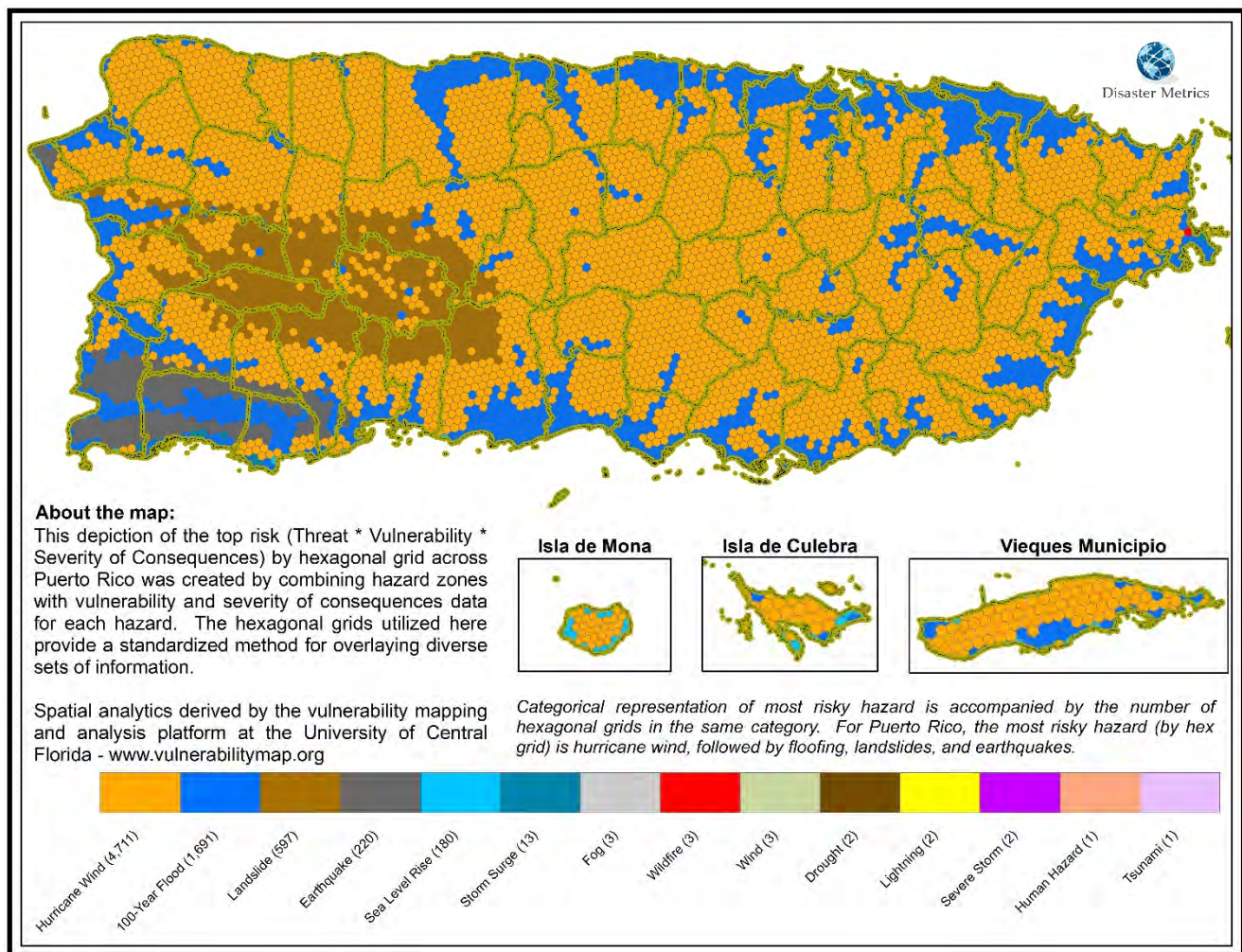


Figure 36: Puerto Rico's Highest Risk Hazards by Hexagonal Grid

Aggregate risk was determined by the sum of risk for each hazard per ½ mile hex grid (Equation 5). Figure 37 shows the aggregate risk in Puerto Rico at the hex grid level.

Equation 5: Total Risk Calculation

$$SUM\ RISK = \sum_{n=1}^{24} RISK_{HAZ_n}$$

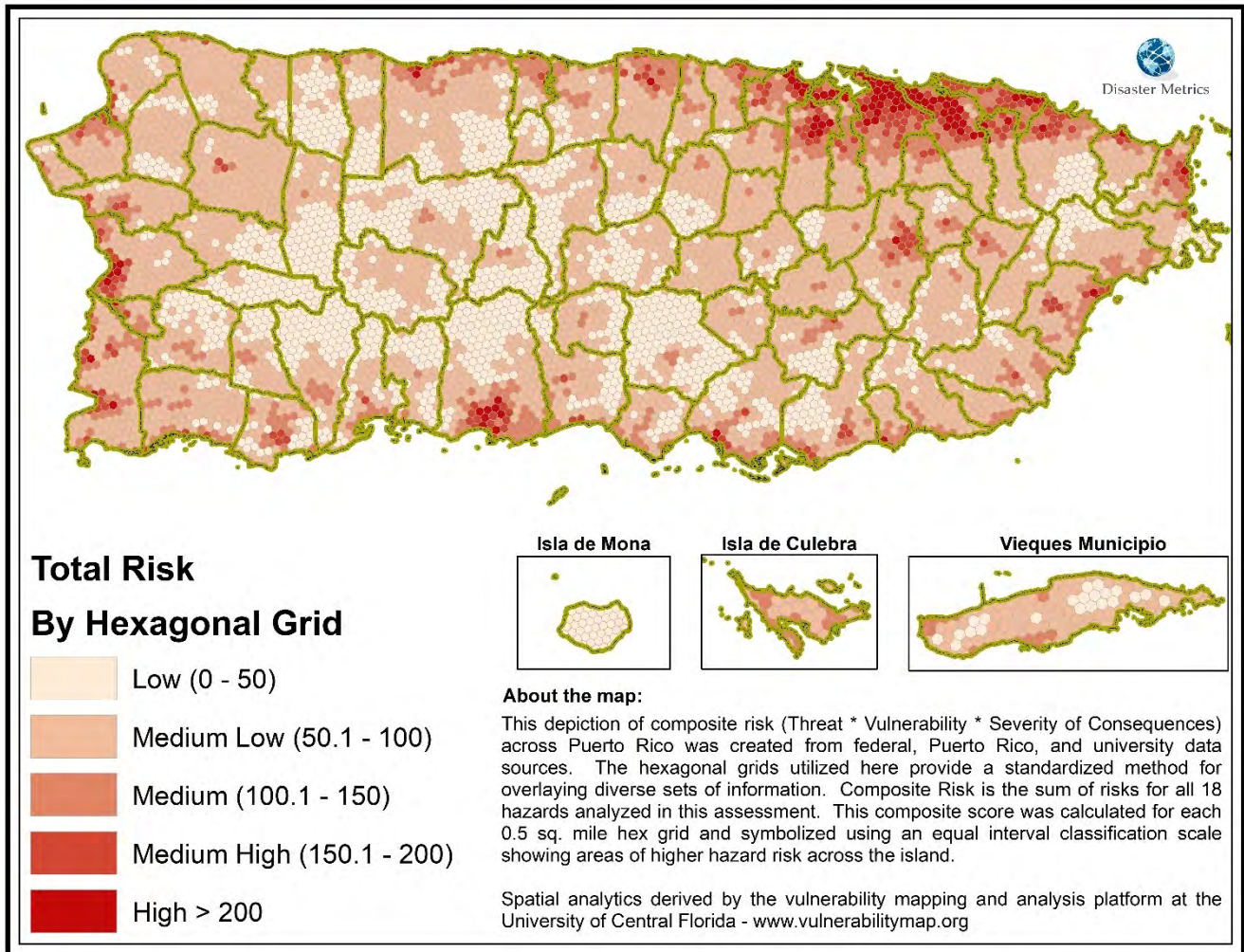


Figure 37: Puerto Rico's Aggregate Risk

Hazards were ranked based on risk at the hex grid level and also at the municipio level. To rank hazards based on risk at the Municipio level, ESRI ArcGIS Pro was used to perform a union between GIS layers of Puerto Rico Municipios and a hex grid with the calculated risk described above and noted in Equation 6. The sum of total risk per hazard per municipio (Figure 38).

Equation 6: Aggregate Hazard Risk Per Municipio Calculation

$$AGGREGATE\ RISK\ PER\ MUNICIPIO = SUM\ RISK$$

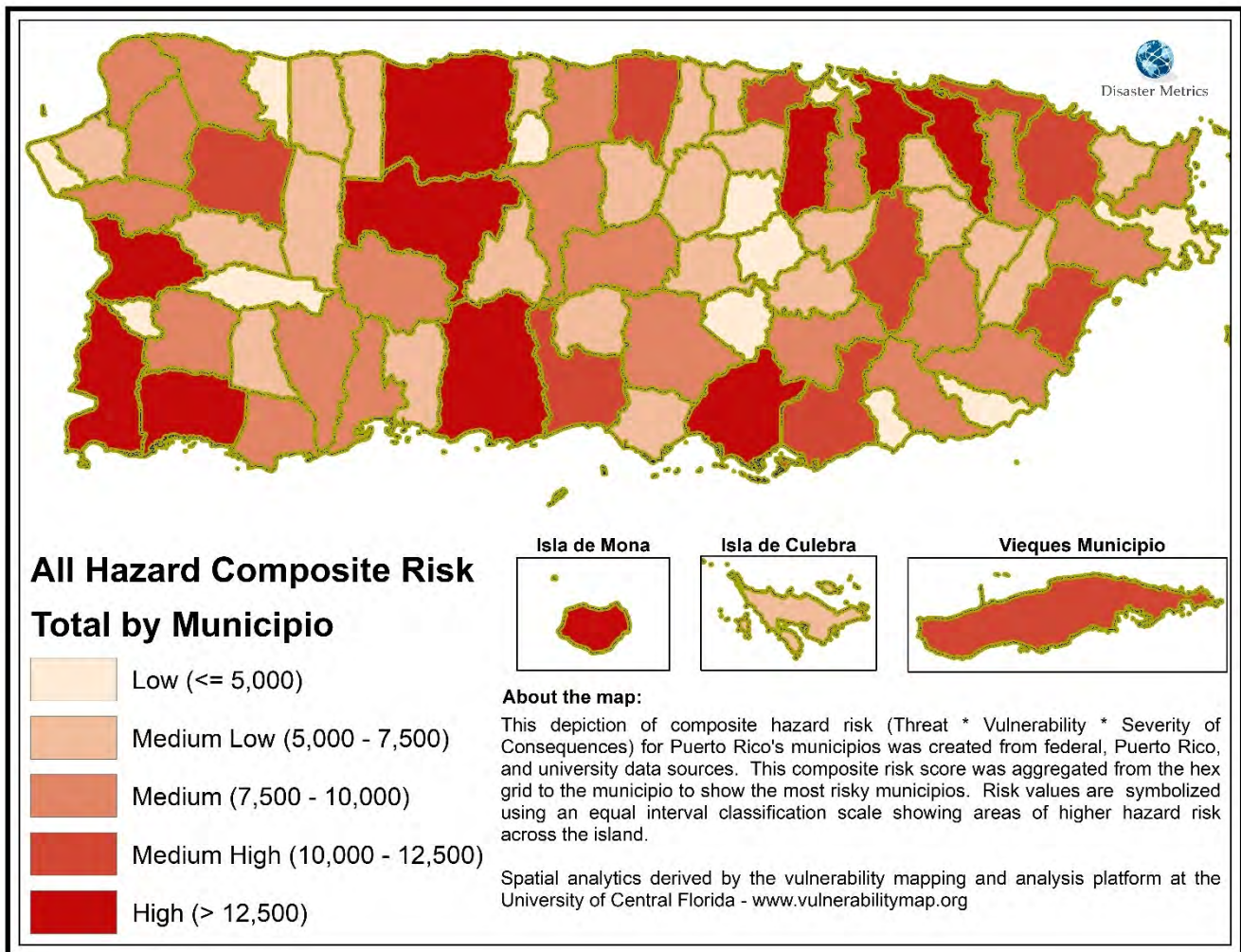


Figure 38: Puerto Rico's Total Risk by Municipio

Total risk was then normalized based on total area of each municipio to provide an area weighted perspective of risks using Equation 7. Figure 39 displays the area weighted risks for each municipio across Puerto Rico.

Equation 7: Hazard Risk Per Municipio Calculation

$$RISK\ PER\ MUNICIPIO = \frac{SUM\ RISK}{AREA\ OF\ MUNICIPIO}$$

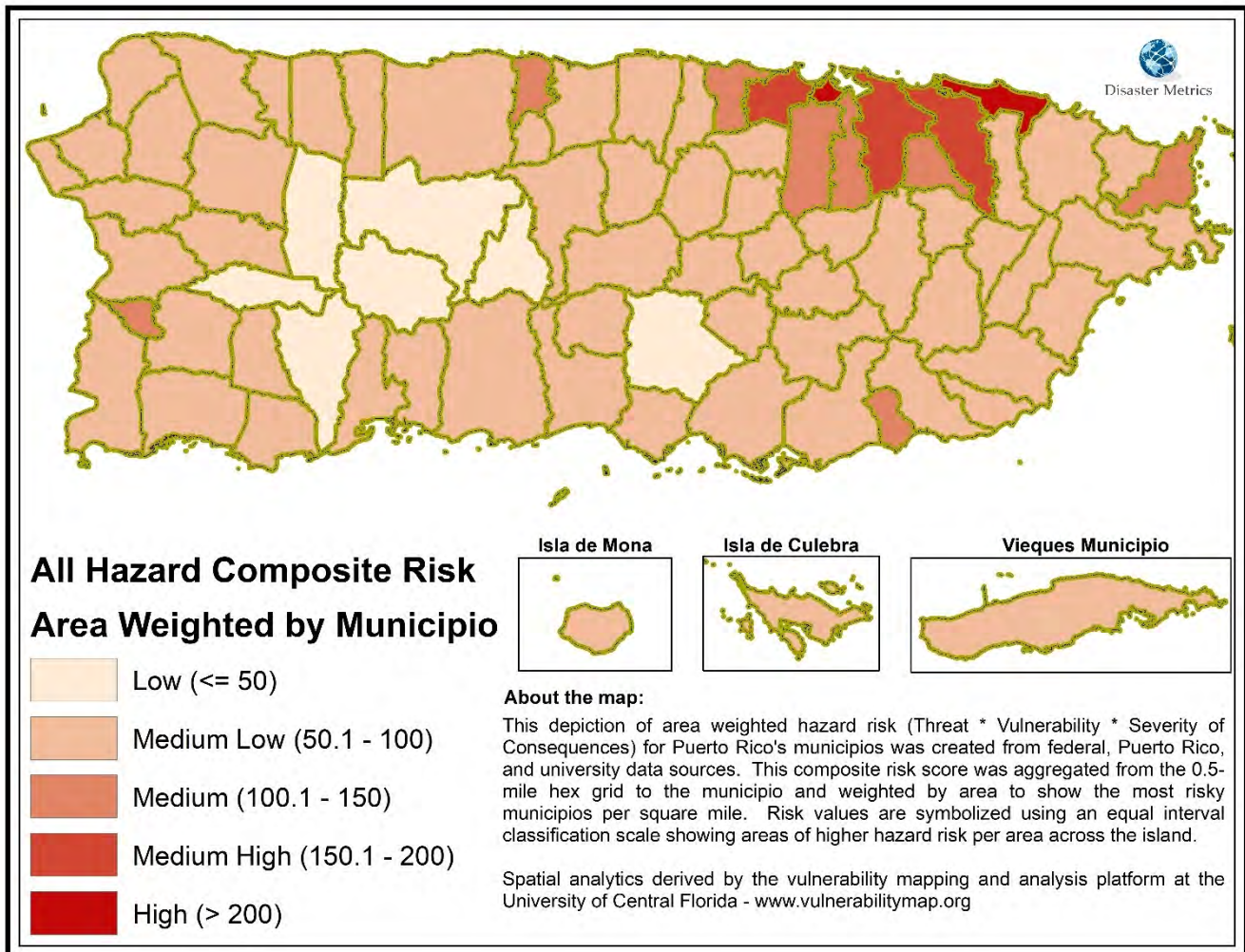


Figure 39: Puerto Rico's Area Weighted Risk by Municipio

Finally, top hazard risks per municipio were selected from the aggregated hazard risk data for each municipio. Mapping the top 2 hazard risks provides a unique perspective into the variety of hazards impacting Puerto Rico (Figure 40) and the more robust list of top 5 hazards per municipio identifies several priority hazards for Puerto Rico in terms of overall risks (Table 103).

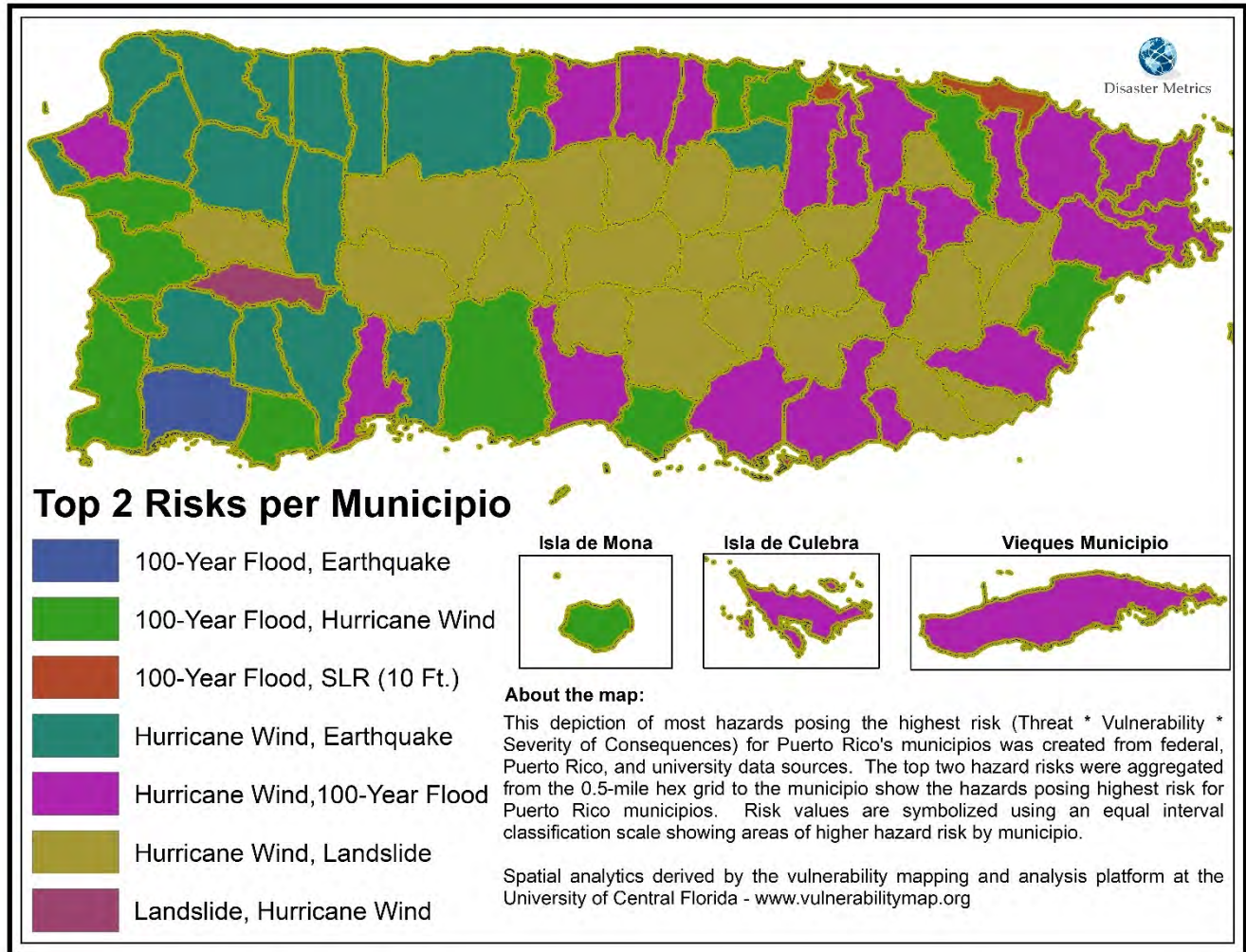


Figure 40: Puerto Rico's Top 2 Hazard Risks by Municipio

Table 103: Top 5 Hazard Risk by Municipio

Municipio	Top Risk	2nd Highest Risk	3rd Highest Risk	4th Highest Risk	5th Highest Risk
Adjuntas	Hurricane Wind	Landslide	Earthquake	100-Year Flooding	Lightning
Aguada	Hurricane Wind	100-Year Flooding	Earthquake	Landslide	Liquefaction
Aguadilla	Hurricane Wind	Earthquake	100-Year Flooding	Landslide	Liquefaction
Aguas Buenas	Hurricane Wind	Landslide	Earthquake	Drought	Severe Storm
Aibonito	Hurricane Wind	Landslide	Drought	Earthquake	100-Year Flooding
Anasco	100-Year Flooding	Hurricane Wind	Earthquake	Landslide	Severe Storm
Arecibo	Hurricane Wind	Earthquake	100-Year Flooding	Landslide	Liquefaction

Municipio	Top Risk	2nd Highest Risk	3rd Highest Risk	4th Highest Risk	5th Highest Risk
Arroyo	Hurricane Wind	100-Year Flooding	Landslide	Earthquake	Drought
Barceloneta	100-Year Flooding	Hurricane Wind	Earthquake	SLR (10 Feet)	Liquefaction
Barranquitas	Hurricane Wind	Landslide	Earthquake	Drought	Wildfire
Bayamon	Hurricane Wind	100-Year Flooding	Earthquake	Landslide	Liquefaction
Cabo Rojo	100-Year Flooding	Hurricane Wind	Earthquake	Liquefaction	SLR (10 Feet)
Caguas	Hurricane Wind	100-Year Flooding	Landslide	Earthquake	Drought
Camuy	Hurricane Wind	Earthquake	Landslide	Liquefaction	100-Year Flooding
Canovanas	Hurricane Wind	100-Year Flooding	Landslide	Earthquake	Severe Storm
Carolina	100-Year Flooding	Hurricane Wind	Earthquake	Landslide	SLR (10 Feet)
Catano	100-Year Flooding	SLR (10 Feet)	Hurricane Wind	Earthquake	Category 5 Storm Surge
Cayey	Hurricane Wind	Landslide	Drought	Earthquake	100-Year Flooding
Ceiba	Hurricane Wind	100-Year Flooding	Landslide	Earthquake	Fog
Ciales	Hurricane Wind	Landslide	Earthquake	Severe Storm	100-Year Flooding
Cidra	Hurricane Wind	Landslide	Drought	Earthquake	100-Year Flooding
Coamo	Hurricane Wind	Landslide	Earthquake	Drought	100-Year Flooding
Comerio	Hurricane Wind	Landslide	Drought	Earthquake	Liquefaction
Corozal	Hurricane Wind	Landslide	Earthquake	Drought	Severe Storm
Culebra	Hurricane Wind	100-Year Flooding	SLR (10 Feet)	Earthquake	Category 5 Storm Surge
Dorado	100-Year Flooding	Hurricane Wind	Earthquake	Liquefaction	SLR (10 Feet)
Fajardo	Hurricane Wind	100-Year Flooding	Earthquake	Landslide	SLR (10 Feet)
Florida	Hurricane Wind	Earthquake	Landslide	Liquefaction	Wildfire
Guanica	100-Year Flooding	Hurricane Wind	Earthquake	SLR (10 Feet)	Landslide
Guayama	Hurricane Wind	100-Year Flooding	Drought	Landslide	Earthquake

Municipio	Top Risk	2nd Highest Risk	3rd Highest Risk	4th Highest Risk	5th Highest Risk
Guayanilla	Hurricane Wind	100-Year Flooding	Earthquake	Landslide	Drought
Guaynabo	Hurricane Wind	100-Year Flooding	Landslide	Earthquake	Human Hazard
Gurabo	Hurricane Wind	100-Year Flooding	Landslide	Earthquake	Drought
Hatillo	Hurricane Wind	Earthquake	Landslide	Liquefaction	100-Year Flooding
Hormigueros	100-Year Flooding	Hurricane Wind	Earthquake	Liquefaction	Landslide
Humacao	100-Year Flooding	Hurricane Wind	Landslide	Earthquake	Drought
Isabela	Hurricane Wind	Earthquake	Landslide	100-Year Flooding	Liquefaction
Jayuya	Hurricane Wind	Landslide	Earthquake	Severe Storm	Liquefaction
Juana Diaz	Hurricane Wind	100-Year Flooding	Earthquake	Landslide	Drought
Juncos	Hurricane Wind	Landslide	100-Year Flooding	Earthquake	Drought
Lajas	100-Year Flooding	Earthquake	Hurricane Wind	Landslide	Liquefaction
Lares	Hurricane Wind	Earthquake	Landslide	Lightning	Severe Storm
Las Marias	Hurricane Wind	Landslide	Earthquake	Severe Storm	Lightning
Las Piedras	Hurricane Wind	Landslide	Earthquake	Drought	Severe Storm
Loiza	100-Year Flooding	SLR (10 Feet)	Hurricane Wind	Category 5 Storm Surge	Liquefaction
Luquillo	Hurricane Wind	100-Year Flooding	Landslide	Earthquake	Liquefaction
Manati	Hurricane Wind	100-Year Flooding	Earthquake	Landslide	Liquefaction
Maricao	Landslide	Hurricane Wind	Earthquake	Severe Storm	Lightning
Maunabo	Hurricane Wind	Landslide	100-Year Flooding	Earthquake	Drought
Mayaguez	100-Year Flooding	Hurricane Wind	Earthquake	Landslide	SLR (10 Feet)
Moca	Hurricane Wind	Earthquake	Landslide	Severe Storm	Liquefaction
Morovis	Hurricane Wind	Landslide	Earthquake	Severe Storm	Liquefaction
Naguabo	Hurricane Wind	100-Year Flooding	Landslide	Earthquake	Liquefaction

Municipio	Top Risk	2nd Highest Risk	3rd Highest Risk	4th Highest Risk	5th Highest Risk
Naranjito	Hurricane Wind	Landslide	Earthquake	Drought	100-Year Flooding
Orocovis	Hurricane Wind	Landslide	Earthquake	Drought	Severe Storm
Patillas	Hurricane Wind	Landslide	100-Year Flooding	Earthquake	Drought
Penuelas	Hurricane Wind	Earthquake	100-Year Flooding	Landslide	Drought
Ponce	100-Year Flooding	Hurricane Wind	Earthquake	Landslide	Drought
Quebradillas	Hurricane Wind	Earthquake	Landslide	100-Year Flooding	Liquefaction
Rincon	Hurricane Wind	Earthquake	Landslide	100-Year Flooding	SLR (10 Feet)
Rio Grande	Hurricane Wind	100-Year Flooding	Landslide	Earthquake	SLR (10 Feet)
Sabana Grande	Hurricane Wind	Earthquake	Landslide	Wildfire	Liquefaction
Salinas	Hurricane Wind	100-Year Flooding	Drought	Earthquake	Landslide
San German	Hurricane Wind	Earthquake	100-Year Flooding	Landslide	Liquefaction
San Juan	Hurricane Wind	100-Year Flooding	Human Hazard	Earthquake	Landslide
San Lorenzo	Hurricane Wind	Landslide	Earthquake	Drought	Severe Storm
San Sebastian	Hurricane Wind	Earthquake	Landslide	Severe Storm	100-Year Flooding
Santa Isabel	100-Year Flooding	Hurricane Wind	Earthquake	Drought	SLR (10 Feet)
Toa Alta	Hurricane Wind	Earthquake	Landslide	100-Year Flooding	Liquefaction
Toa Baja	100-Year Flooding	Hurricane Wind	SLR (10 Feet)	Earthquake	Liquefaction
Trujillo Alto	Hurricane Wind	Landslide	Earthquake	100-Year Flooding	Drought
Utuado	Hurricane Wind	Landslide	Earthquake	100-Year Flooding	Lightning
Vega Alta	Hurricane Wind	100-Year Flooding	Earthquake	Landslide	Liquefaction
Vega Baja	Hurricane Wind	100-Year Flooding	Earthquake	Landslide	Liquefaction
Vieques	Hurricane Wind	100-Year Flooding	SLR (10 Feet)	Earthquake	Category 5 Storm Surge
Villalba	Hurricane Wind	Landslide	Earthquake	100-Year Flooding	Severe Storm

Municipio	Top Risk	2nd Highest Risk	3rd Highest Risk	4th Highest Risk	5th Highest Risk
Yabucoa	Hurricane Wind	100-Year Flooding	Landslide	Earthquake	Drought
Yauco	Hurricane Wind	Earthquake	Landslide	100-Year Flooding	Drought