

## **COMMUNITY RESILIENCE TO CLIMATE CHANGE: A SOCIO-ECOLOGICAL CASE STUDY FROM PUERTO RICO**

### **Authors**

Tatiana Abatemarco (Bennington College, Bennington, VT, USA)

Tatiana M. Gladkikh (University of Vermont, Burlington, VT, USA)

Elvia J. Melendez-Ackerman (University of Puerto Rico at Rio Piedras, San Juan, PR, USA)

Christopher J. Nytech (Friends of El Yunque Foundation, PR, USA)

### **Summary**

As a result of climate change, both cyclonic storms (e.g., hurricanes) and droughts are increasing in severity and frequency around the globe. Additionally, sea level is rising. This poses a particular challenge for island communities. This case study looks at Puerto Rico, a U.S. territory located in the Caribbean. Puerto Rico was struck by two hurricanes (Irma and Maria) in the span of two weeks in September 2017. In addition to the environmental pressures of climate change, the island has also experienced social and political upheaval, resulting in a twofold challenge to community resilience. This socio-environmental synthesis case study integrates biophysical, historical, governance, and socio-economic analyses of Puerto Rico to consider the role of community resilience as a strategy for climate adaptation. It focuses on the eastern region of the island surrounding El Yunque National Forest (El Yunque), illustrated through the story of La Vega community.

## **History Subsystem Narrative**

### **A Decolonial History of Puerto Rico**

The history of Puerto Rico reaches back to the Cretaceous period, 145-66 million years ago. The first human inhabitants of Puerto Rico are believed to have been on the island in 4000 BCE, as documented at the Angostura site in Mantí. El Yunque was revered as a holy place for the prehistoric Taino inhabitants of Puerto Rico, and today it is esteemed as a wonder of the natural world, having been proclaimed a Biosphere Reserve under the UNESCO Man and Biosphere program in 1976.

The Taíno had a population of about 3 million across the Caribbean before Spanish colonizers arrived and devastated their land and people. The Taíno ancestors began settling the islands of the Caribbean around 400 BCE and cultivated many crops including corn, sweet potatoes, and beans. The story told by historians for decades was that the Taíno were “killed off” or “extinct.” Recent DNA evidence, however, shows that, “61 percent of all Puerto Ricans have Amerindian mitochondrial DNA, 27 percent have African and 12 percent Caucasian.” This suggests a more complex story of colonization and racial mixing.

The Taíno people were brutalized by the Spanish, suffering from small pox, starvation, and the abject violence of slavery and war. It is estimated that 85% of the Taíno died as a result of the Spanish invasion. Both Spanish and African immigrants (kidnapped for slavery) had children with the Taíno, resulting in a mixed race population. Words from the Taíno language are used today; for example, the name “El Yunque” comes from the Taino word “Yuké” which means “white lands.” Today, you can still find both ancient petroglyphs as well as modern depictions of these images. The story of Taíno extinction and the fact that they are still not federally recognized shows the persistence of colonial oppression in Puerto Rico.

The Spanish lost their hold on Puerto Rico in 1898 when Spain ceded the island to the United States in the Treaty of Paris, at the end of the Spanish-American War. Prior to this, Spain had actually granted some autonomy to Puerto Rico through the Autonomic Charter of 1897. The autonomous legislature only met once before the United States acquired Puerto Rico. Had the United States incorporated Puerto Rico, the island’s residents would have had the full constitution apply to them. The United States opted to make Puerto Rico an unincorporated territory, which meant that island residents were denied full U.S. citizenship. This was a similar policy to Native American communities on the mainland U.S. Both Puerto Ricans and Native Americans were viewed as unfit for both full citizenship and sovereignty by the U.S. government. In 1917 citizenship was granted to Puerto Ricans, but not the full citizenship of other U.S. citizens. Puerto Ricans still could not vote in federal elections unless they resided on the mainland U.S., and Puerto



Rico does not have voting representation in the U.S. Congress, nor does Puerto Rico have a seat in the Senate.

Puerto Rico is the oldest continually colonized location in the world. What this means is that Spain, and then the United States has facilitated the outward flow of resources. The sugarcane plantations alone removed soil wealth and continually pushed small landholders off the land well into the 20th century. This process of accumulation of resources by colonizers manifests in the present day as a debt crisis for Puerto Rico. This is a similar circumstance in nearly all U.S. colonial locations, where the lack of sovereignty creates high debt and a volatile local economy. This lack of economic autonomy and long history of extraction of natural and financial resources was exacerbated by Hurricane Maria, which facilitated disaster capitalism and a new influx of U.S. business profiting off the Puerto Rican people.

On September 20, 2017, Hurricane Maria, a category 5 storm, hit Puerto Rico. This was on the heels of Hurricane Irma, a category 4 storm, which had hit the island just 10 days prior. The hurricane caused widespread devastation, due to high winds, flooding, and mudslides. The island experienced loss of power, which has lasted for years, as the power grid has not been adequately repaired. It has been called the longest power outage in U.S. history. Estimates of death from the hurricane and aftermath range 2,975 (George Washington University) to 5,740 (Harvard University). As climate change accelerates, the Caribbean will see increased hurricane activity and a rise in sea levels. Ironically, climate change also increases the length and severity of droughts in the region. A warmer climate holds more water in the atmosphere, meaning stronger storms and longer droughts.



Figure 2. Hurricane Maria. Source: NOAA.gov



Figure 3. Aftermath of the Maria. Source: Carlos Giusti - AP

The challenges of climate change and colonialism loom large over Puerto Rico in the present day. Many people and organizations are working to resist the extraction of resources and adapt to the new climate regime. Resilience is the ability for a community to withstand shocks and reorganize after catastrophic events. Community resilience projects are happening across the island, from the formation of community groups making disaster preparedness plans, to protests in the street to confront government corruption, to relocalizing the food system. These small interventions hold

the promise of an island that can better respond to the threat of climate change and create a sustainable and just economy.

## References

Did you know that El Yunque is one of the oldest forest reserves in the Western Hemisphere? (2007). USDA Forest Service. Retrieved from [https://www.fs.usda.gov/Internet/FSE\\_DOCUMENTS/stelprdb5338937.pdf](https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5338937.pdf)

El Yunque history. USDA Forest Service. Retrieved from [https://www.fs.usda.gov/detail/elyunque/about-forest/?cid=fsbdev3\\_042958](https://www.fs.usda.gov/detail/elyunque/about-forest/?cid=fsbdev3_042958)

Fusté, J. (2017). Repeating islands of debt: Historicizing the transcolonial relationality of Puerto Rico's economic crisis. *Radical History Review*, 128.

Garcia Goyco, O. (n.d.) Pre-Columbian history of Puerto Rico. Encyclopedia of Puerto Rico.

GW Researchers: 2,975 Excess Deaths Linked to Hurricane Maria (29 Aug 2018). GW Today. Retrieved from <https://gwtoday.gwu.edu/gw-researchers-2975-excess-deaths-linked-hurricane-maria>

Koshore et al. (2018). Mortality in Puerto Rico after Hurricane Maria. *New England Journal of Medicine*, 379, 162-170. DOI: 10.1056/NEJMsa1803972

Poole, R.M. (Oct 2011). What became of the Taino? Smithsonian Magazine. Retrieved from <https://www.smithsonianmag.com/travel/what-became-of-the-taino-73824867/>

<https://puertoricosyllabus.com>

## Governance Subsystem Narrative

### Governance structures

Puerto Rico is a Caribbean territory of the United States of America that operates under the constitution of the Commonwealth of Puerto Rico. Puerto Rico's central governance structure is delivered by executive, legislative and judicial powers which are based in those of the US. The executive branch manages 139 agencies and public corporations. The island is divided into 78 municipalities (the primary legal subdivision) for political and administrative purposes. Each municipality is a legal entity with a local government somewhat equivalent to a US state county and subordinated to the Constitution of the Commonwealth of Puerto Rico. Municipalities are grouped into 8 Senatorial (2 Senators/District) and 40 House Districts that provide citizens from multiple municipalities legislative representation that is complimented with representation through elected lawmakers through island-wide cumulative votes (Figure 4). Since 2017, the US Congress mandated that the island's central government's budget be approved by a Financial Oversight and Management Board of seven non-elected official nominated by the US President and approved by the US Congress and one ex officio member designated by the Governor of Puerto Rico. Under the federal law, residents of Puerto Rico, the majority-US citizens, are unable to have representation in Congress and to vote for the president of the United States.



*Figure 4. Capitol Building and site of the Legislative Branches (House and the Senate) of the Commonwealth of Puerto Rico located in Old San Juan. Source: <https://www.senado.pr.gov/>*

### Río Grande

A municipality also known as City of El Yunque (Figure 5) covers an area of 157.3 km<sup>2</sup> divided into 10 sectors (or *barrios* in Spanish) that together support a total population of 52,362 people. Services are delivered through a governance structure that combines the interaction of municipal, state and federal and executive and legislative powers. The municipal executive branch includes: the Majors' Office, Municipal Clerk, Municipal Finances, Department of Transportation and Public Works, Office of Administration of Human Resources, Office of Sports and Recreation,

Municipal Police, Internal Audit, Emergency and Disasters Management (a liaison office that responds to the State’s Emergency and Disasters Management Program), an Office of Federal Programs (an advisory office that responds to the State’s Office of Federal Programs) and an Office for Tourism Development an advisory office that responds to the State’s Office of Federal Programs. All but the last two offices respond to the Major’s Office. The Emergency Management Office reports to the State management Office and the Office of Federal Programs. Municipal ordinances are evaluated and approved by a municipal assembly of 15 people representing the 10 municipality sectors. The major and the assembly members are elected by every four years.



Figure 5. Location map of Puerto Rico in the Caribbean, showing the eastern region (in yellow) and El Yunque National Forest (in green). Map from El Yunque National Forest 2018 Revised Management Plan.

## Governance processes

All municipalities’ local environmental and socio-economic development and its land use planning are highly tied to state and federal governance structures. For example, management and land use classification of selected land areas within the Municipality are the direct responsibility of state (e.g., **Land Authority, Department of Agriculture**) or federal agencies (**US Forest Service**). The US Forest Service has a US mandate to the management, use and access control of approximately 1/3 of the land within Río Grande (Figure 6) and a portion of surrounding municipalities that contain lands pertaining to El Yunque National Forest. Its newly released management plan calls for the involvement of surrounding communities in the management of EYNF. In matters of transportation, maintenance of primary road connectors among Río Grande sectors is the state’s **Department of Transportation’s** responsibility and that of secondary roads falls of the Municipality. The state’s **Authority of Roads and Transportation** develops and finances transportation infrastructure projects. **The Puerto Rico Aqueduct and Sewer Authority (PRASA)** is a public corporation with 1.3M clients, 97% of which are supplied with potable water and 59% with sewer services. NON-PRASA drinking water systems are regulated by PRASA.

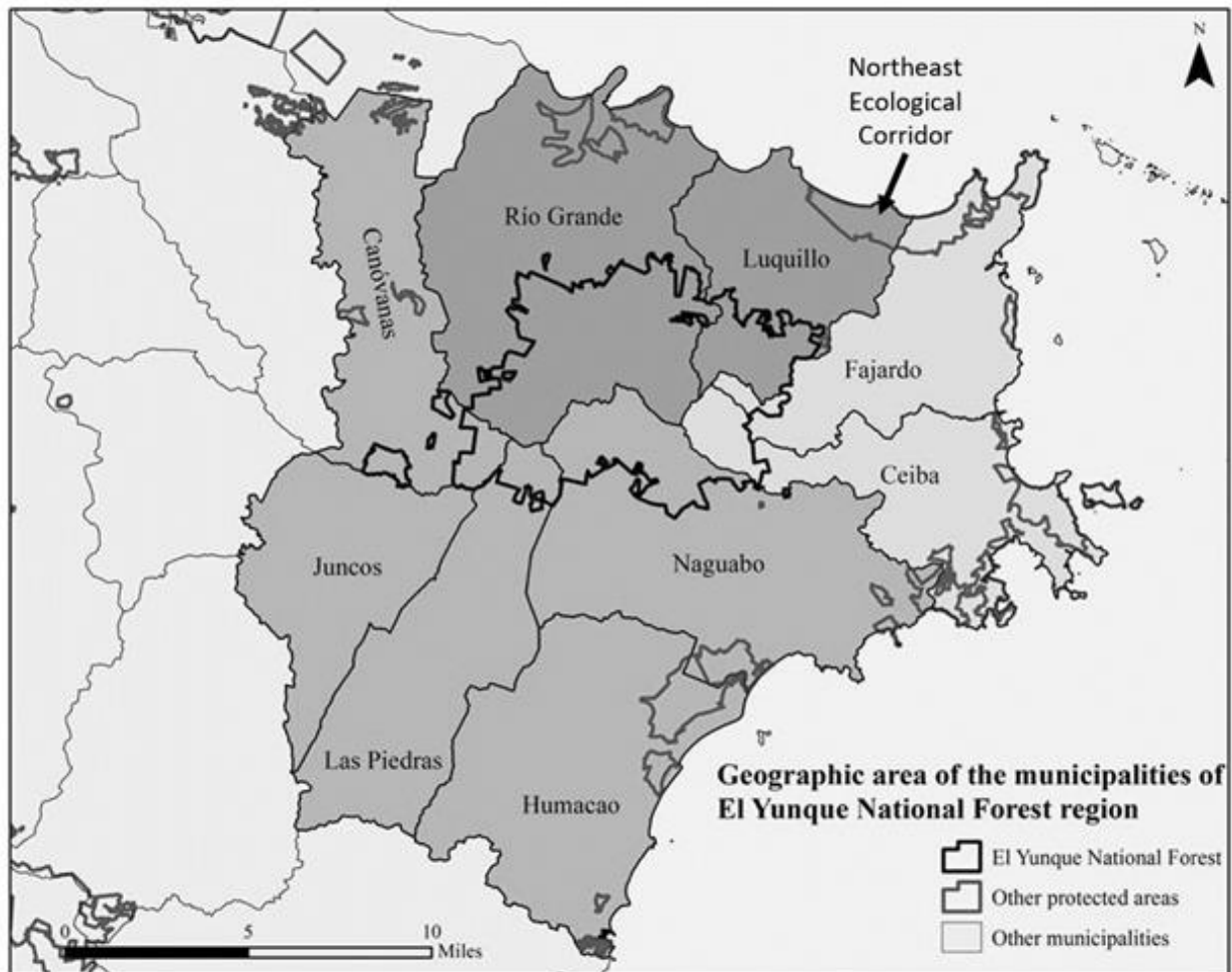


Figure 6. Map of the nine municipalities of the eastern region in Puerto Rico, showing the location of El Yunque National Forest (bold black outline) and other protected areas, including the Northeast Ecological Corridor. Map modified from El Yunque National Forest 2018 Revised Management Plan.

Infrastructure improvements to the aqueduct and sewer systems are funded primarily by PRASA and to a minor extent by the private sector. The **Puerto Rico Power Authority**, also a public corporation that in terms of customers served is one of the largest power utilities in the US providing electricity to 1.4M clients. Congress through the **Financial Oversight and Management Board** seeks to privatize this service on the island. The **US Army Corps of Engineer (USACE) – Jacksonville District Area** is a key player for the design and funding of engineering activities related to engineering and construction associated to impacts to waterways in all municipalities of Puerto Rico (bridges, dams, channelization, etc.) but its main point of interaction are with state or federal agencies. The **Federal Emergency Management Agency (FEMA)**, an agency of the US Department of Homeland Security, is charged with the support of citizens and emergency personnel in the preparation, protection, response, recovery and mitigation of all hazards. Following Hurricane Maria, Community Recovery Centers in Puerto Rico, were jointly coordinated with FEMA and the state government. One was established in Río Grande.

## References

Federal Emergency management Agency (2010). The Federal Emergency Management Agency. Publication 1. Retrieved from [https://www.fema.gov/media-library-data/20130726-1823-25045-8164/pub\\_1\\_final.pdf](https://www.fema.gov/media-library-data/20130726-1823-25045-8164/pub_1_final.pdf)

Federal Emergency Management Agency (2017). Community Recovery Centers. Retrieved from <https://www.fema.gov/disaster/4339/crc>

Financial Oversight and Management Board for Puerto Rico (2019). 2019 Fiscal Plan for the Puerto Rico Electric Power Authority As certified by the Financial Oversight and Management Board for Puerto Rico on June 27, 2019. Retrieved from <https://oversightboard.pr.gov/fiscal-management-responsibilities/>

Gobierno de Puerto Rico-Departamento de Seguridad Publica (2017). Tu línea de Servicios 311: Directorio de Agencias de Puerto Rico. Retrieved from <https://spnavigation.respondcrm.com/AppViewer.html?q=https://311prkb.respondcrm.com/respondweb/Directorio%20de%20Agencias%20de%20PR/Directorio%20de%20Agencias%20de%20PR.pdf>

Gobierno de Puerto Rico – Junta de Planificación (2010). Plan Territorial del Municipio de Río Grande. Memorial 30 de Junio 2010 [Online] Retrieved from <http://jp.pr.gov/Portals/0/Planes%20Territoriales/PT%20-%20Rio%20Grande/Rio%20Grande%20PT%20-%20Memorial.pdf?ver=2018-01-11-231249-280>

Gobierno de Puerto Rico – Portal Oficial. (2019a). Constitución del Estado Libre Asociado de Puerto Rico. Retrieved from <https://www2.pr.gov/SobrePuertoRico/Documents/elaConstitucion.pdf>

Gobierno de Puerto Rico – Portal Oficial (2019b). Municipio de Río Grande. Retrieved from <https://www2.pr.gov/Directorios/Pages/InfoMunicipio.aspx?PRIFA=M119>

LexJuris (2019). Act 162 of 2011 (PR 117). Retrieved from <http://www.lexjuris.com/lexlex/Leyes2011/lexl2011162.htm>

Puerto Rico Aqueduct and Sewer Authority (2013). Moving towards financial stability and sustainability. Retrieved from <https://www.acueductospr.com/INVESTORS/download/Presentations%20to%20Investors/20130517%20Puerto%20Rico%20Credit%20Conference%202013.pdf>

Skolte, E (2013). An overview of projects and missions in the Antilles. Retrieved from <https://www.saj.usace.army.mil/Media/News-Stories/Article/479618/an-overview-of-projects-and-missions-in-the-antilles/>





US Army Corps of Engineers – Jacksonville District (2019). Retrieved from <https://www.saj.usace.army.mil/About/Divisions-Offices/Construction/Antilles-Area-Office/>

US Census (2019). Geography Program Glossary: Puerto Rico. Retrieved from <https://www.census.gov/programs-surveys/geography/about/glossary.html#pr>

US Forest Service Region 8 (2018). El Yunque National Forest: Revised Land Management Plan. R8-MB 152 A. Retrieved from [https://www.fs.usda.gov/Internet/FSE\\_DOCUMENTS/fseprd592253.pdf](https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd592253.pdf)

### **Biophysical Subsystem Narrative**

Puerto Rico is an archipelago in the eastern Caribbean centered on the geographic coordinates 18°15' N by 66°30' W that includes the main island and several smaller islands to the east and west (Figure 5). It is the smallest of the Greater Antilles with a total land area of approximately 9,000 km<sup>2</sup>. The eastern region of the island is comprised of nine municipalities: Río Grande, Luquillo, Fajardo, Ceiba, Naguabo, Humacao, Las Piedras, Juncos, and Canóvanas (Figure 6). The geographic area of the eastern region is 86.9 km<sup>2</sup>. There are several geologic terranes, including marine volcanoclastic rocks, intrusive igneous rocks, and chert sedimentary rocks, accompanied by surficial deposits of non-volcanic biogenic material including river alluvium, beach and swamp deposits, and artificial fill. The region's landforms are topographically diverse, rising steeply from the coastal plain to over 1000 m in elevation in the Luquillo Mountains in a span of just 5 miles. They support a stunning diversity of habitats ranging from wetlands and sandy beaches, agricultural pastures and shrublands, to secondary and primary montane forests.

At the core of the eastern region lies El Yunque National Forest. It is the only tropical and most biologically diverse forest in the United States National Forest System. The forest's green infrastructure provides landscape-scale habitat for dozens of rare terrestrial and aquatic plants and animals of conservation concern, including the critically endangered Puerto Rican Parrot, Coqui tree frogs, and rare orchids (Figure 7). This conserved area also provides a variety of invaluable ecosystem services to nearby human communities, such as clean air and water. Ten rivers originate within El Yunque, supplying drinking water for about 20% of Puerto Rico's population. The sequestration and storage of carbon by primary and secondary vegetation and soil resources in El Yunque generates important climate regulation benefits. Several smaller protected areas are distributed throughout the region, including the Northeast Ecological Corridor (NEC), a coastal natural reserve spanning the municipalities of Luquillo and Fajardo. It is one of the last untouched stretches of littoral and marine habitat in the northern part of the island and serves as nesting habitat for leatherback turtles. In the foothills surrounding El Yunque there is a mosaic of pasture and shrublands that support small-scale farming and cattle ranching. The low-lying plains and coastal areas are heavily built-up with urban, suburban, and exurban development, along with commercial and industrial infrastructure, and a dense network of roads, many in need of maintenance.

Puerto Rico's climate is tropical maritime, with the warm trade winds blowing from the east and maintaining temperatures between approximately 70 and 95 °F. While rainfall is distributed throughout the year, January through March tend to be drier months, and May through November is typically the rainy season. In the eastern region, the presence of high mountains causes warm, moist air to rise and cool, creating an orographic effect which influences rainfall and vegetation patterns. Coastal areas receive an average of 1500 mm yearly and are characterized by subtropical dry and humid forest while the highest peaks in El Yunque receive up to 5000 mm of rain annually which supports montane wet and rain forest ecosystems. The excessive rainfall together with steep slopes can lead to saturated soils and landslides as well as flash flooding of downstream river valleys. The eastern region, and Puerto Rico in general, are in the path of hurricanes that can bring damaging winds and torrential rain, causing widespread ecological and social disturbance. Major

cyclonic storms affected the region in 1989 (Hugo), 1998 (Georges), and 2017 (Irma & María), and several communities in the region are still recovering from the most recent events.

Research suggests that the major impacts of climate change in Puerto Rico over the course of the 21<sup>st</sup> century will result from four major stressors: sea level rise, increased severity of tropical storms, increased drought, and increased heat extremes. The first stressor is likely to have a direct impact on low-lying coastal communities in the region, leading to inundation and displacement and movement inland. This may increase pressure to develop arable land at mid-to-upper elevations, further fragmenting forested landscapes with human infrastructure. An increase in super storms of great intensity will further stress vulnerable food and energy systems, augmenting the health and economic risks faced by local communities. Climate change is projected to result in water shortages throughout the Caribbean within the coming decades due to an overall decrease in annual rainfall. Increased drought will stress natural communities, potentially limiting key ecosystem services such as the provision of food and water resources. In Puerto Rico, including the eastern region, water availability and the potential for drought is exacerbated by reduced storage capacity in the island's reservoirs due to sedimentation and the lack of maintenance in recent decades, excessive loss of potable water from broken and obsolete distribution infrastructure, and a lack of political will and financial resources to remedy these problems. Furthermore, an increase in extreme heat events has been linked with public health issues such as heat-related mortality among urban populations. Together, the impending challenges of climate change signal the need for sustainability and resiliency initiatives to both mitigate and adapt to extreme events of all kinds.



Figure 7. The Puerto Rican parrot (*Amazona vittata*) (left), the common coqui (*Eleutherodactylus coqui*) (middle), and the Luquillo Mountains baby root orchid (*Lepanthes eltoroensis*) (right). Sources: Wikimedia

## References

El Yunque National Forest Revised Land Management Plan. 2018. USDA Forest Service R8-MB 152A. [https://www.fs.usda.gov/Internet/FSE\\_DOCUMENTS/fseprd592253.pdf](https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd592253.pdf)

Fourth National Climate Assessment, Chapter 20: US Caribbean.

<https://nca2018.globalchange.gov/chapter/20/>

Gould, W.A.; Alarcon, C.; Fevold, B.; Jimenez, M.E.; Martinuzzi, S.; Potts, G.; Quinones, M.; Solórzano, M.; and E. Ventosa. 2008. The Puerto Rico Gap Analysis Project Volume 1: land cover, vertebrate species distributions, and land stewardship. Gen. Tech. Rep. IITF-39.

Helmer, E. H. (2004). Forest conservation and land development in Puerto Rico. *Landscape Ecology*, 19(1), 29-40.

Khalyani, A. H., Gould, W. A., Harmsen, E., Terando, A., Quinones, M., & Collazo, J. A. (2016). Climate change implications for tropical islands: Interpolating and interpreting statistically downscaled GCM projections for management and planning. *Journal of Applied Meteorology and Climatology*, 55(2), 265-282.

Jennings, L. N., Douglas, J., Treasure, E., & González, G. 2014. Climate Change Effects in El Yunque National Forest, Puerto Rico, and the Caribbean Region. Gen. Tech. Rep. SRS-GTR-193. Asheville, NC: USDA-Forest Service, Southern Research Station. 47 p., 193, 1-47.

Marrero, T. D. M. L. (2003). The Study of Land Cover Change in a Caribbean Landscape: What Has Happened in Eastern Puerto Rico during the Last Two Decades? *Caribbean Studies*, 5-36.  
Méndez-Lázaro, P., Martínez-Sánchez, O., Méndez-Tejeda, R., Rodríguez, E., Morales, E., & Schmitt-Cortijo, N. 2015. Extreme heat events in San Juan Puerto Rico: Trends and variability of unusual hot weather and its possible effects on ecology and society. *Journal of Climatology and Weather Forecasting*, 3(2), 1-7.

Méndez-Lázaro, P. A., Pérez-Cardona, C. M., Rodríguez, E., Martínez, O., Taboas, M., Bocanegra, A., & Méndez-Tejeda, R. 2018. Climate change, heat, and mortality in the tropical urban area of San Juan, Puerto Rico. *International journal of biometeorology*, 62(5), 699-707.  
Puerto Rico Department of Housing. 2018. Disaster Recovery Action Plan for the use of CDBG-DR Funds in Response to Hurricanes Irma and Maria. Retrieved March 6, 2019 from [http://www.cdbg-dr.pr.gov/wp-content/uploads/2018/07/HUD-Approved-Action-Plan\\_EN.pdf](http://www.cdbg-dr.pr.gov/wp-content/uploads/2018/07/HUD-Approved-Action-Plan_EN.pdf)

Miller, G., & Lugo, A. E. (2009). Guide to the ecological systems of Puerto Rico. USDA Forest Service Gen. Tech. Rep. *IITF-GTR-35*. [https://data.fs.usda.gov/research/pubs/iitf/iitf\\_gtr\\_35.pdf](https://data.fs.usda.gov/research/pubs/iitf/iitf_gtr_35.pdf)

Murphy, S.F., and Stallard, R.F., eds., 2012, Water quality and landscape processes of four watersheds in eastern Puerto Rico: U.S. Geological Survey Professional Paper 1789, 292 p. <https://pubs.usgs.gov/pp/1789/PP1789.pdf>

Quiñones, M., Parés, I.K., Gould, W.A., González, G., McGinley, K., & Ríos, P. El Yunque National Forest and Luquillo Experimental Forest Atlas. June 2018. USDA Forest Service Gen. Tech. Rep. IITF-GTR-47. <https://www.fs.usda.gov/treearch/pubs/56095>

Scalley, T. H., & Lopez-Marrero, T. D. M. (2014). Land-cover composition, water resources and land management in the watersheds of the Luquillo Mountains, northeastern Puerto Rico. *Caribbean Geography*, 19, 43-68.

[https://data.fs.usda.gov/research/pubs/iitf/ja\\_iitf\\_2014\\_Heartsill001.pdf](https://data.fs.usda.gov/research/pubs/iitf/ja_iitf_2014_Heartsill001.pdf)

Sosa Pascual, O., Álvarez, L., Saint-Pré, P., Mejía, M., & Rodríguez Velázquez, V. 24 April 2019. La Mala Gestión del Agua Agrava el Impacto de la Sequía en el Caribe. Centro de Periodismo Investigativo. Retrieved May 1 2019 from <http://periodismoinvestigativo.com/2019/04/la-mala-gestion-del-agua-agrava-el-impacto-de-la-sequia-en-el-caribe/>

USGCRP. 2018: Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II: Report-in-Brief [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, 186 pp.

Weaver, P. L. 2012. The Luquillo Mountains: forest resources and their history. Gen. Tech. Rep. IITF-44. U.S. Department of Agriculture Forest Service, International Institute of Tropical Forestry, Rio Piedras, PR. <https://www.fs.usda.gov/treearch/pubs/44055>

### **Socio-economic Subsystem Narrative**

The eastern region of Puerto Rico surrounding El Yunque National Forest (El Yunque) includes nine municipalities: Canovanas, Ceiba, Fajardo, Juncos, Humacao, Las Piedras, Luquillo, Naguabo, and Río Grande. El Yunque is the predominant land cover within the region, and the forest covers about 13% of land within the area. Río Grande encompasses the largest area of the forest within its boundaries (33% of the municipality's area) and Naguabo has the smallest area (0.1% of municipality is national forest). Humacao does not have any of its land within the boundary of El Yunque, but is included as part of the management area surrounding the forest.

The total population of the region is about 322,000 people with almost equal proportions of males and females (see Figure 11 for gender and Figure 12 for age distribution). Similar to the rest of the island, the region is experiencing a population decline following Hurricane María in 2017. The US Census estimates suggest that between 2015 and 2017 the population in the study region decreased by about 2,700 people. Island-wide, about 123,000 people left Puerto Rico in 2018, compared with 78,000 in 2017.

Municipalities within the region contain a diversity of land uses and economic activities. Some of the main sources of economic activities include education, health, and social services, retail, manufacturing, and recreation. For instance, Río Grande and Fajardo possess some of the most luxurious beachfront resorts on the island. Ceiba provides an important maritime connection: ferries to and from Culebra and Vieques - two other inhabited islands of the Puerto Rico archipelago - depart from these municipalities. Roosevelt Roads Naval Station, a former US Naval base, is located in Ceiba and represents a significant former land use whose development footprint continues to impact the landscape to this day. Luquillo is a famous culinary destination for local seafood; it also hosts the Luquillo Long-Term Ecological Research Program - the only tropical terrestrial site in the U.S. Long-Term Ecological Research (LTER) Network. The main entrance to El Yunque passes through Río Grande along Rt. 191, and there are numerous small, local businesses located along the way. Humacao hosts one of the campuses of the University of Puerto Rico. Canovanas is known as the "race town," as the only remaining horse-racing track in Puerto Rico is located there. Medical and pharmaceutical manufacturing is one of the main economic activities in Juncos and Las Piedras municipalities. Small-scale farming and tourism are some of the main economic activities in Naguabo.



Figure 8. Resort in Río Grande. Source: yamsafer.com



Figure 9. Puerto del Rey Marina in Fajardo. Source: marinas.com



Figure 10. Road into El Yunque. Source: enciclopediapr.org.

Socio-economic characteristics within the region are quite diverse. The average unemployment rate is 21% (2017 estimate); Naguabo has the lowest unemployment rate (11%) and Fajardo has the highest (28%). These formal numbers, however, might not be representative of actual employment - the informal labor market in Puerto Rico is quite prevalent. The average household income varies across municipalities (Table 1). For the region, the median household income is \$19,635 and the mean household income is \$28,822 (income in the past 12 months in 2017 inflation-adjusted dollars). Poverty rates in the region are high - 46% of the population is considered in poverty, compared to the national poverty rate of 12 % (2018). The US Census Bureau considers a household in poverty if the household's total income is less than the family's threshold; the official poverty thresholds do not vary geographically.

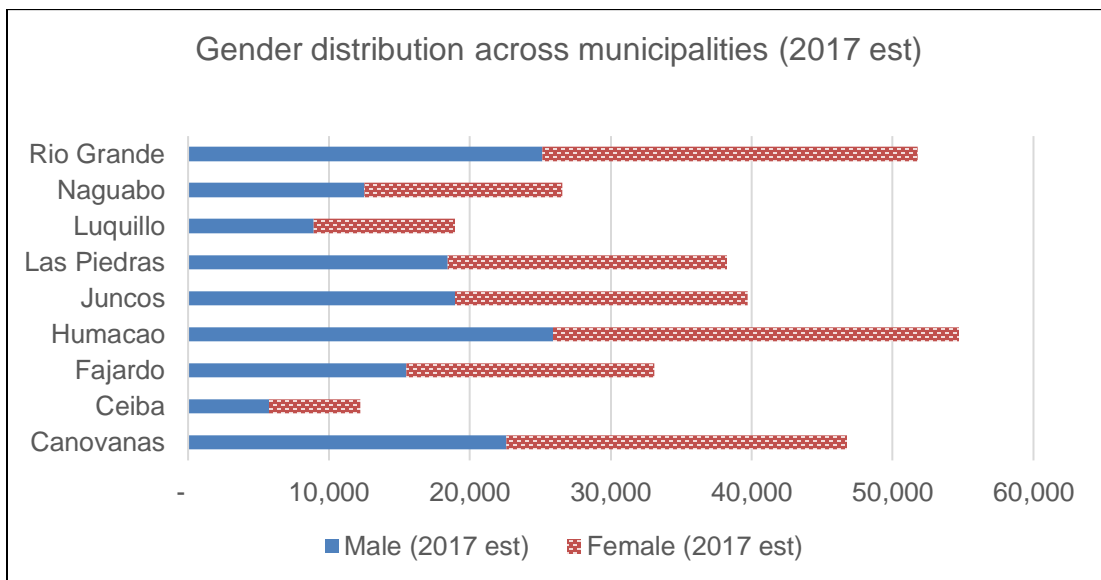


Figure 11. Gender distribution across municipalities (US Census; 2017 estimates)

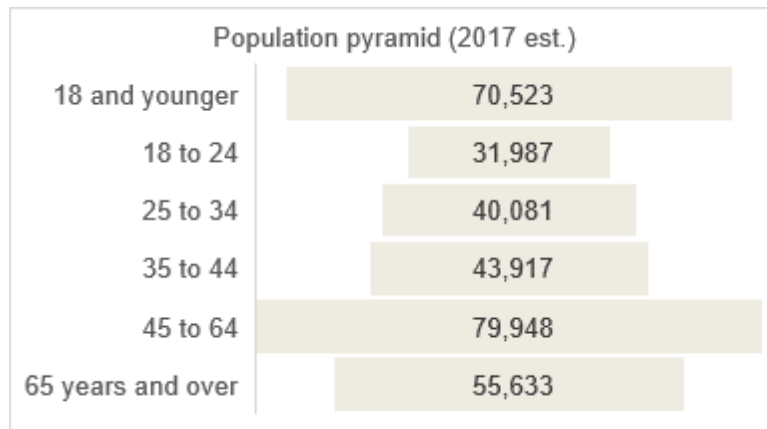


Figure 12. Population pyramid for the region (US Census; 2017 estimates)

Table 1. Median and mean household income.

| Municipality | Income in the past 12 months<br>(in 2017 inflation-adjusted dollars) |          |                                |                |                                |        |
|--------------|--|----------|--------------------------------|----------------|--------------------------------|--------|
|              | Percent population<br>poverty (2017 est.)                            | of<br>in | Median<br>(household,<br>est.) | income<br>2017 | Mean<br>(household, 2017 est.) | income |
| Canovanas    | 44%  |          | \$                             | 19,986         | \$                             | 30,888 |
| Ceiba        | 43%  |          | \$                             | 18,998         | \$                             | 31,024 |
| Fajardo      | 45%  |          | \$                             | 18,941         | \$                             | 27,035 |
| Humacao      | 45%  |          | \$                             | 18,735         | \$                             | 30,464 |
| Juncos       | 47%  |          | \$                             | 18,533         | \$                             | 24,598 |
| Las Piedras  | 49%  |          | \$                             | 20,587         | \$                             | 28,636 |
| Luquillo     | 46%  |          | \$                             | 19,377         | \$                             | 28,238 |
| Naguabo      | 53%  |          | \$                             | 18,976         | \$                             | 28,107 |
| Rio Grande   | 39%  |          | \$                             | 22,584         | \$                             | 30,411 |
| Average      | 46%  |          | \$                             | 19,635         | \$                             | 28,822 |

## References

Flores, A., & Krogstad, J. M. (26 July 2019). Puerto Rico’s population declined sharply after hurricanes Maria and Irma. Pew Research Center. <https://www.pewresearch.org/fact-tank/2019/07/26/puerto-rico-population-2018/>

U.S. Census Bureau, 2013-2017 American Community Survey 5-Year Estimates.

U.S. Census Bureau (27 Aug 2019). How the Census Bureau Measures Poverty. Retrieved from <https://www.census.gov/topics/income-poverty/poverty/guidance/poverty-measures.html>



U.S. Census Bureau. (Sep 10 2019). Income and Poverty in the United States: 2018. Retrieved from <https://www.census.gov/library/publications/2019/demo/p60-266.html>

USDA Forest Service. (2016). Draft Revised Land and Resource Management Plan. El Yunque National Forest (No. R8-MB 148 A; pp. 126).

Weaver, P.L. 2012. The Luquillo Mountains: Forest resources and their history. General Technical Report IITF-44, USDA Forest Service, International Institute of Tropical Forestry, San Juan, Puerto Rico. 159 p.

## Resilience Narrative

### Defining Resilience

The use of the term “resilience” has become wide spread across disciplines specially in the last 25 years. It is term that originated from the ecological systems theory (ecological resilience) to describe the process and capacity of ecosystems to withstand a disturbance without changing self-organized processes and structures. As the use of this term has expanded across other disciplines and specially to include social systems, this original definition which was based on assumptions of ecosystem equilibria and stability now has evolved considerably. Social-ecological resilience had been defined as *the ability of linked social-ecological systems to deal with disturbance while keeping their capacity for adaptation, learning and transformation*. When focused solely on social systems van Breda defines social resilience as *a multilevel process that systems engage in to obtain better-than-expected outcomes in the face or wake of adversity*. Both definitions assume that resilience occurs across multiple system domains (e.g. social: individual, community, municipality vs. ecological: organism, population, community). The social-ecological definition, however, is also meant to include natural or man-made biophysical systems (e.g. forests, buildings) and how they are influenced and respond to disturbance events. For these biophysical systems, the process of resilience can be deconstructed into a persistence, recovery and reorganization stages that may result in transitions to alternative states which do not necessarily retain critical functions when the system is not resilient. In the face of global changes brought about by phenomena such as climate change (e.g. increase in extreme events, sea level rise), population growth, rapid urbanization and associated human activities (overfishing, deforestation etc.) the concept of resilience has been increasingly used to inform public policy and sustainability initiatives world-wide. The resilience cycle is a framework used by many jurisdictions to plan, develop and implement activities along an iterative process where individuals and organizations may improve resilience.

### **The Resilience Cycle**



Figure 13. The resilience cycle framework for building community resilience. Source NOAA (2015).

## References

Falk, D. A., Watts A. C., Thode A.E. 2019. Scaling Ecological Resilience. *Frontiers in Ecology and Evolution* 7:275. DOI 10.3389/fevo.2019.00275

Folke, C., S. R. Carpenter, B. Walker, M. Scheffer, T. Chapin, and J. Rockström. 2010. Resilience thinking: integrating resilience, adaptability and transformability. *Ecology and Society* 15(4): 20. [online] URL: <http://www.ecologyandsociety.org/vol15/iss4/art20/>

Holling CS (1973) Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics* 4: 1-23.

van Breda, Adrian D. (2018). A critical review of resilience theory and its relevance for social work. *Social Work* 54(1), 1-18. <https://dx.doi.org/10.15270/54-1-611>

NOAA 2015. NOAA Coastal Community Resilience Indicators and Rating Systems. Accessed on Nov 9, 2019. [Online] URL: <https://coast.noaa.gov/data/digitalcoast/pdf/resilience-indicators.pdf>

Wilkinson, C. 2012. Social-ecological resilience and planning: an interdisciplinary exploration. University of Stockholm. Accessed on Nov 9, 2019 [online] URL: <https://www.diva-portal.org/smash/get/diva2:546171/SUMMARY01.pdf>

## La Vega Narrative

*Note: This narrative was written with input from the Center for Landscape Conservation (a non-governmental organization that works in the region and in La Vega. Feedback was also sought from members of the community. The narrative will be updated as necessary if/when additional comments are received.*

Hurricane María's cyclonic winds started to pick up around midnight in the areas around El Yunque National Forest (El Yunque), in small, working-class communities like La Vega, in Río Grande, and farms located throughout the northeast part of the island. Many of these communities were still recovering from Hurricane Irma that had passed north of Puerto Rico just two weeks before. That storm had knocked out the municipal water system and electric grid for thousands of residents and service had not yet returned. By daybreak on September 20, 2017, María made landfall, bringing sustained wind speeds of up to 150 mph that toppled trees and ripped roofs off many buildings. Almost 20 inches of rain fell on the lands around El Yunque over the course of two days. It saturated the steep montane soils and swelled the rivers. As in previous extreme climate events the rain sent tons of water, mud, broken branches, boulders and vegetation downstream, flooding roads and damaging bridges. This included PR Route 961, the one access

point into and out of La Vega. The community's 150 families, many of them with elderly members, were trapped.

In the immediate aftermath of the storm, residents of La Vega began the long process of recovery within their homes and community. Church groups prepared and distributed meals, bottled water, and clothes to those in need. Some people had generators and gasoline and shared an extension cord with their neighbors to charge their phones or run a refrigerator for a few hours a day. After the waters receded, a brigade of residents cleared debris from the road and bridge using machetes and chainsaws, allowing vehicles to pass once again. Relief materials began to arrive from municipal and non-governmental organizations working in the region, among them the Center for Landscape Conservation (CLC) non-governmental organization (NGO). The CLC provided food, water filters, solar lamps, medicine and clinical supplies needed by some residents. Later came additional aid from the FEMA. International allies also provided support, including a volunteer team from Burlington, VT that helped clear storm debris and restore damaged agricultural lands. Water service returned to La Vega after two months, once power was available to run the supply pumps. Electricity for the entire community was restored six months after the storm. Some residents noticed that Colinas, the neighboring community just a few hundred meters to the north and closer to the urban center, had their utilities restored earlier.

In June of 2018, and as an initiative of the CLC to promote local governance and empowerment, the residents of La Vega organized a community group, Friends and Neighbors of El Yunque. The CLC worked with the group to foster sustainable development initiatives related to strengthening governance, local self-sufficiency, and improving quality of life. The CLC also directed funds from other organizations and private donations to sponsor several activities, such as the preparation of sealed food storage containers and the discussion of a community agro-business to sell products in nearby restaurants. Other needs identified by the community were attended to, like the elimination of clandestine dumps in vacant lots. Residents of La Vega also engaged in disaster preparation planning with the University of Puerto Rico School of Public Health, and the Puerto Rico Community Foundation (an NGO), to bolster resilience to extreme climate events like hurricanes and drought that are anticipated to worsen in the region. Participants conducted an analysis of community risks, strengths, resources and opportunities, which led to prioritizing needs such as training for a local chainsaw crew to rapidly remove debris blockages in the road, and establishing communication with state authorities about repairing the bridge. The planning process also resulted in the design of a community resource hub that can provide food and basic medical supplies, harvest rainwater, and produce renewable electricity should access to external sources be compromised in the future. With the help of the CLC, Friends and Neighbors of El Yunque submitted a proposal for funding to construct the resource hub.

Two years after María, many challenges remain in La Vega and other communities around El Yunque. Although various restoration activities have occurred, several of the resilience planning initiatives have yet to materialize. A community's capacity to adapt to changing climatic conditions is a product of its socio-cultural demographics, financial resources, and dominant structural conditions (e.g., land tenure, knowledge, wealth, historical context and political power) that inform the worldviews and priorities of its residents. For example, despite the immediate proximity to El Yunque and its vast biophysical and cultural assets that could potentially bolster

local resilience, economic factors remain a dominant force that drives many development and resource management decisions in the region. Another important element that influences resiliency is the governance framework, including the organizations and institutions that are present, their focal themes, and the scales at which they work. Around El Yunque, municipal offices and NGO partners are recognized as primary contacts for implementing local development strategies, while federal agencies such as FEMA and the US Army Corps of Engineers are key partners for large-scale regional projects. For farmers, resource options include actors from public and academic sectors, including the University of Puerto Rico Agricultural Extension Service and the Natural Resources Conservation Service. Even though a robust network of support and resources may be present, the timing of opportunities does not always align with a community’s ability to organize itself. Residents’ levels of interest, energy and availability to participate in activities can wax and wane over time. The upshot is that increased resilience is not guaranteed. Further examination of these and other variables can help develop a comprehensive understanding of the complex dynamics at play in social-ecological systems such as La Vega and identify leverage points for intervening in the system to generate more resilient, sustainable outcomes.

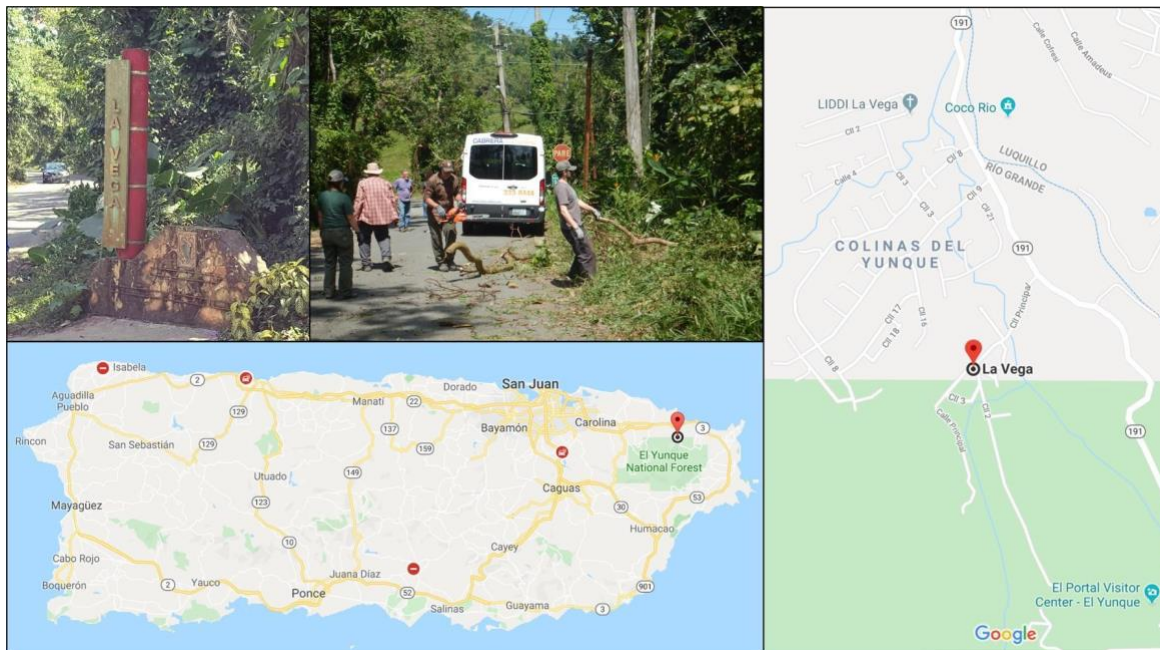


Figure 14. Image credits: Christina Erickson, Edgardo González, and Google Maps.