



# Impacts of a Changing Climate on Ecosystem and Biodiversity in the U.S. Caribbean

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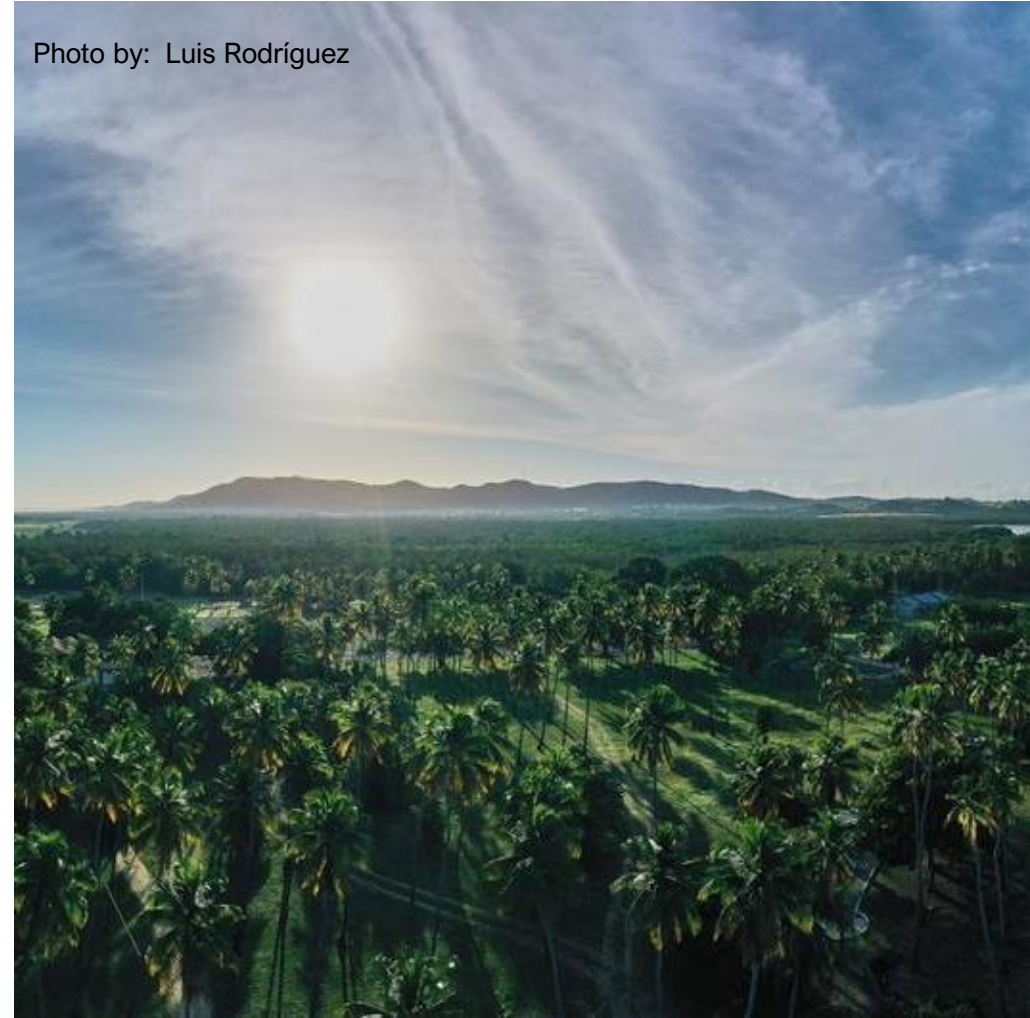
Patricia Chardón-Maldonado, Ph.D.  
NOAA in the Caribbean Annual Partners Meeting  
June 21, 2023

# Introduction

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- Coastal and terrestrial ecosystems provide numerous goods and services that are vital to the islands' economies and the well-being of their residents.
- Ecosystems provide provisioning, regulating, cultural, and supporting services.
- The changing climate compromises ecosystem goods and services.

Photo by: Luis Rodríguez



# Climate & Non-Climate Stressors (Examples)

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Extreme precipitation – droughts - frequent and intense tropical cyclones - steady increase of surface temperature – sea level rise - pollution – deforestation

# Observed and Projected Climate Change for the US Caribbean

Sources: OCM 2017; Puerto Rico Climate Change Council 2022; Sweet et al. 2022

## 1

### TEMPERATURE

Minimum temperatures are increasing faster than daily average temperatures.

Projections for end-of-century temperatures show additional warming, from as low as 1.1°F (SSP2-4.5) to as high as 7°F under a very high scenario (SSP5-8.5).

# Observed and Projected Climate Change for the US Caribbean

Sources: OCM 2017; Puerto Rico Climate Change Council 2022; Sweet et al. 2022

## 2

### RAINFALL

Climate models project a significant reduction in annual average rainfall by the end-century with cuts of 10% for SSP2-4.5 and 33% for SSP5-8.5.

# Observed and Projected Climate Change for the US Caribbean

Sources: OCM 2017; Puerto Rico Climate Change Council 2022; Sweet et al. 2022

## 3

### TROPICAL CYCLONES

There is high confidence that the number of intense tropical cyclones reaching categories 4 and 5 will likely increase as the climate warms.

The number of tropical cyclones impacting Puerto Rico has increased over the past 25 years (1996-2021).

# Observed and Projected Climate Change for the US Caribbean

Sources: OCM 2017; Puerto Rico Climate Change Council 2022; Sweet et al. 2022

## 4

### SEA LEVEL RISE

Sea levels will continue to rise for centuries, reaching 2.3–5.4 m by 2300 and much beyond.

Long-range sea level scenarios indicate a further rise of approximately 0.2 m (Low scenario ) to 0.4 m (High scenario) by 2050 and 0.4 m (Low scenario) to 2.1 m (High scenario) by 2100.

# Observed and Projected Climate Change for the US Caribbean

Sources: OCM 2017; Puerto Rico Climate Change Council 2022; Sweet et al. 2022

## 5

### OCEAN ACIDIFICATION

Surface seawater pH levels from 1988 to 2020 decreased at  $-0.017 \pm 0.0002$  units per decade. The current surface ocean is 12% more acidic (based on  $H^+$  concentration) than in 1988.

Atmospheric  $CO_2$  levels have continued to increase, reaching 415 ppm in June 2021.



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Sources: OCM 2017; Puerto Rico Climate Change Council 2022; Sweet et al. 2022

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# Coastal Zones

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- The US Caribbean coastline is roughly 876 miles in length (Puerto Rico: 700 miles and US Virgin Islands: 175 miles) and is composed of:
  - sandy dunes
  - beaches
  - mangroves
  - salt flats
  - coral reefs
  - seagrass beds
- High population density, concentrated development, and critical infrastructure are within 0.6 miles of the coastline.
- Beaches are assets of public domain, or public trust lands, with minor exceptions.



Photo from Facebook



Photo by: Vida Marina



Photo by: Vida Marina



Photo by: Patricia Chardón



Photo by: Patricia Chardón

# Coastal Zones

- Extraction of sand from the beaches and dunes for construction purposes (during the 1960s and 1970s) once caused severe damage for an extended period.
- Erosion has drastically reduced the width of some beaches.
- The destruction of the dunes has contributed to coastal erosion as they form a reservoir of sand that could supply sand to the beach during storms.

Photo by: Patricia Chardón

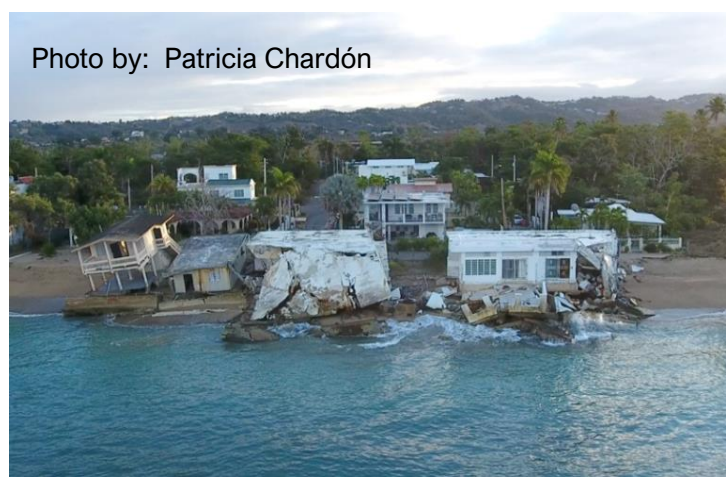


Photo by: Sociedad Ambiente Marino

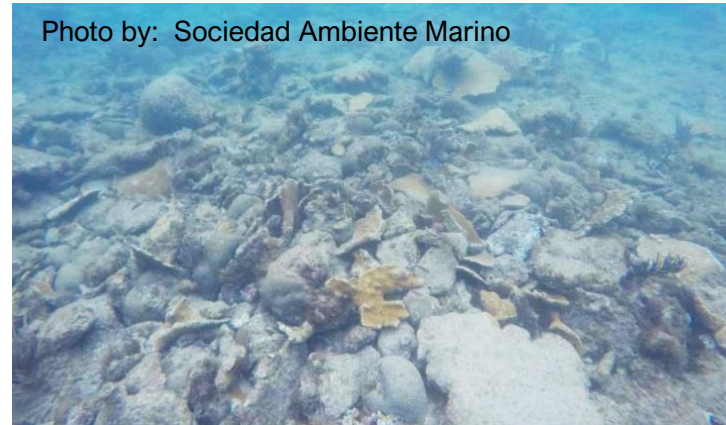
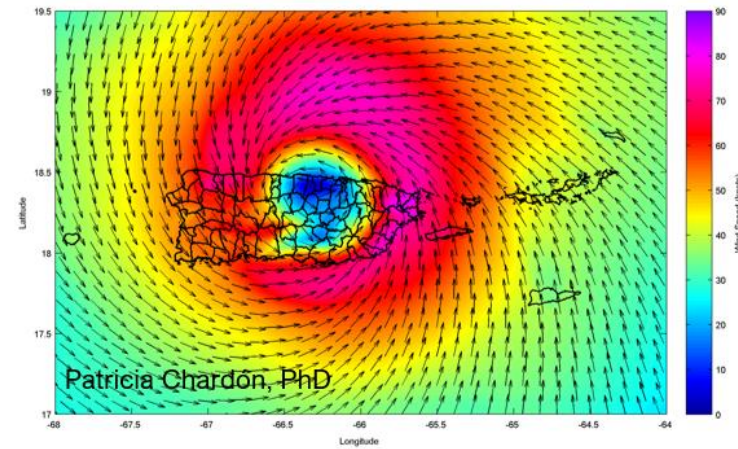
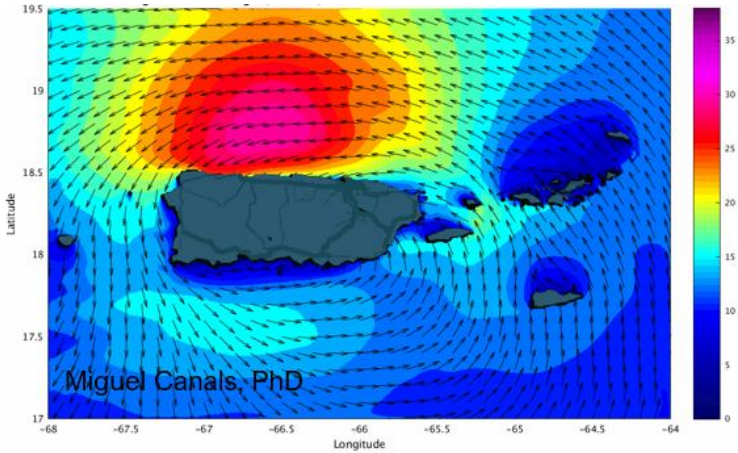


Photo by: Vida Marina



# Coastal Zones

- The wave action and intense rainfall from hurricanes Irma and Maria alone:
  - damaged over 12% of coral reefs
  - caused beach loss of 1.2 to 3.1 miles
  - eroded dunes
  - devastated almost 33% of mangroves



Sources: Gochfeld et al. 2020; Toledo-Hernández et al. 2018; Viehman et al. 2020; Browning et al. 2019; Cox et al. 2019; Pérez-Valentín and Müller 2020; Bendik et al. 2021; Cartier 2019

# Coastal Zones



Coastal Vulnerability Indices for various portions of the USVI (Guannel et al. 2022)

- The final estimate of coastal vulnerability shows that St. Croix is the most vulnerable of all islands because of the preponderance of long stretches of sandy beaches and higher wave climate.
- Many beaches are moderate to highly vulnerable to coastal hazards, especially to sea-level rise and storm surges.

# Coral Reefs

- Threatened by coral disease (e.g., Stony Coral Tissue Loss Disease), pollution, climate change (e.g., ocean acidification), and other stressors.
- Puerto Rico – Surrounded by over 1,930 mi<sup>2</sup> of shallow coral reef ecosystems
- US Virgin Islands – 187 mi<sup>2</sup> area is covered by coral reefs and corals on hard bottom
- Coral reef monitoring programs in Puerto Rico (PRCRMP) and USVI (TCRMP) show a mean reduction of **34%** in coral cover over the last two decades.



Photo by: Sea Grant  
Puerto Rico



Photo by: Sociedad Ambiente  
Marino



Photo by: Melissa  
Meléndez

Sources: NOAA Coral Reef Conservation Program, 2020; Puerto Rico Coral Reef Monitoring Program, USVI Territorial Coral Reef Monitoring Program; National Coral Reef Monitoring Program; Causey et al. 2002

# Coral Reefs

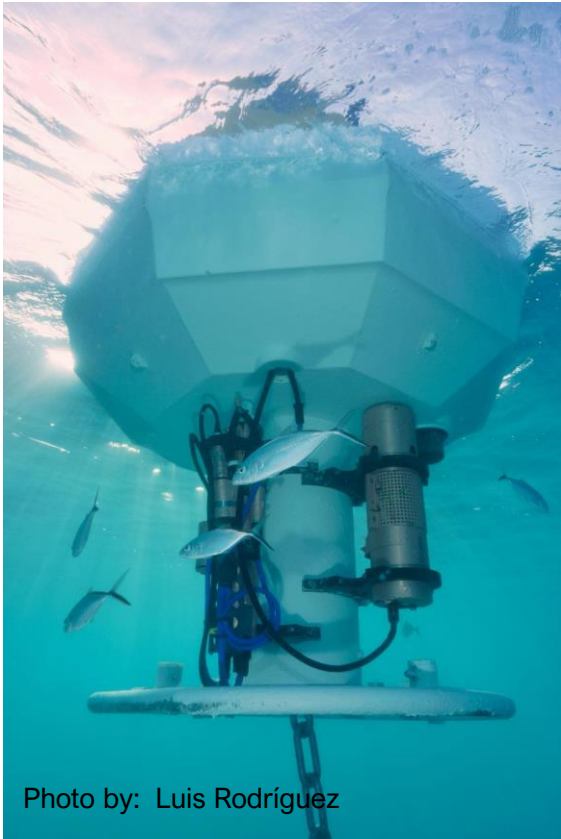
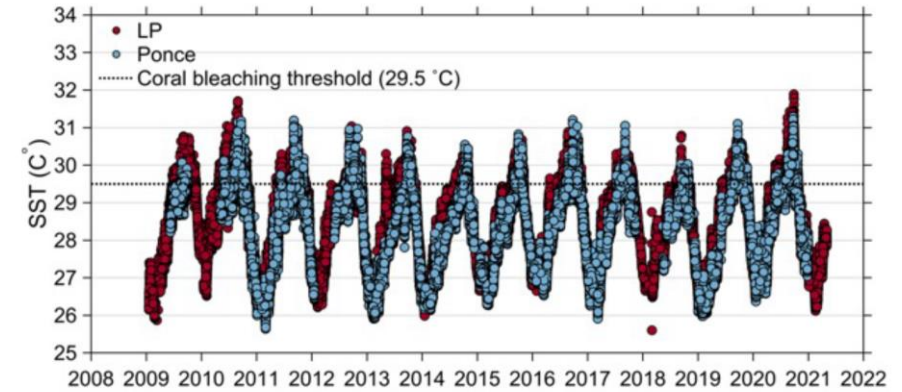
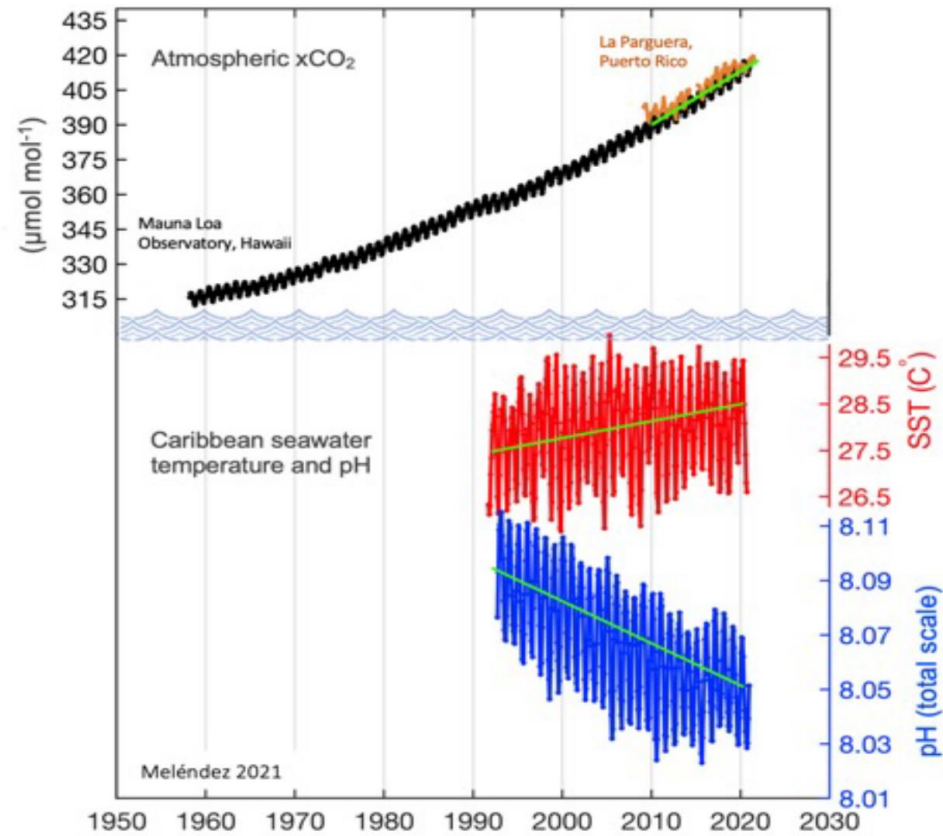


Photo by: Luis Rodríguez



Coastal Protection  
Sand Production  
Tourism - Recreation  
Fisheries



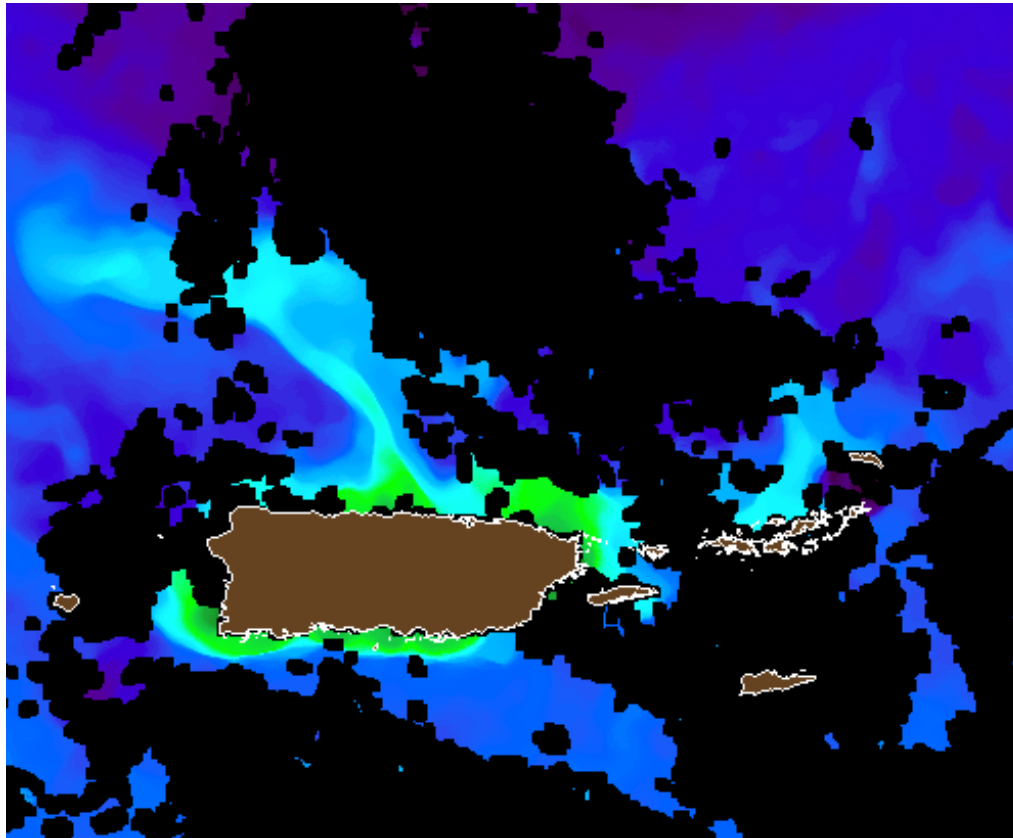
Habitat Loss  
Land Based Pollution  
Management - Restoration

## Coral Reefs

- In **2005**, the U.S. Caribbean suffered a major coral bleaching event, followed by a disease outbreak where the U.S. Virgin Islands lost nearly half of its corals in an extensive die-off.
- Major bleaching occurred again in both **2010** and **2019**.
- In **2017**, Hurricanes Irma & Maria struck the US Caribbean coral reefs with devastating force, damaging over 12% of coral reefs.

Sources: NOAA Coral Reef Conservation Program, 2020; Puerto Rico Coral Reef Monitoring Program, USVI Territorial Coral Reef Monitoring Program; National Coral Reef Monitoring Program; Gochfeld et al. 2020; Toledo-Hernández et al 2018; Viehman et al 2020





# Coral Reefs

- Sediment and contaminant runoff derived from various land-based activities could directly impact coral regeneration capacity, growth, mortality, and ecosystem services they provide.
- Could obstruct sunlight and limit photosynthesis of aquatic plants, reduce biologically available oxygen, and increase water temperature.

# Caribbean Forests

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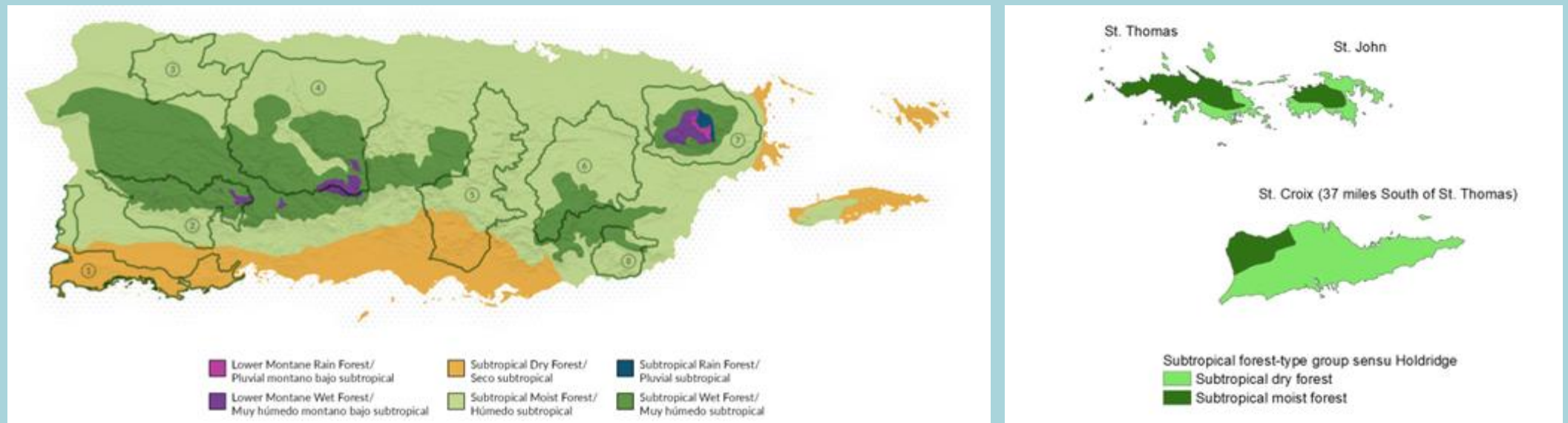
- Forests in the US Caribbean (ranging from coastal mangroves and dry forests to forests on the mountain peaks) provide many services, including watershed and coastal protection, economic benefits (e.g., fruit and wood), cooling in urban environments, and improved water quality, recreation, habitat, and biodiversity protection.

Photo by: Patricia Chardón



# Caribbean Forests

- A total of 46,967 acres of forest area (57.2% forest cover) was estimated in 2014 for the US Virgin Islands.
- The US Virgin Islands experienced forest loss from 56,607 acres (68.9% forest cover) in 1994 to 46,564 acres (56.7% forest cover) in 2004. The overall forest area has been relatively stable. However, the ongoing fourth forest inventory could provide new observations/trends. (Marcano-Vega and Williamson, 2014).
- The total forest land estimated for Puerto Rico was 1.15 million acres in 2019 (52.7% forest cover).
- Forest structural changes in Puerto Rico during the period of 2004 to 2019 show that net volume, live tree above-ground biomass, and live tree carbon remain relatively stable (Brandeis, T.J., Marcano-Vega, H. 2022)



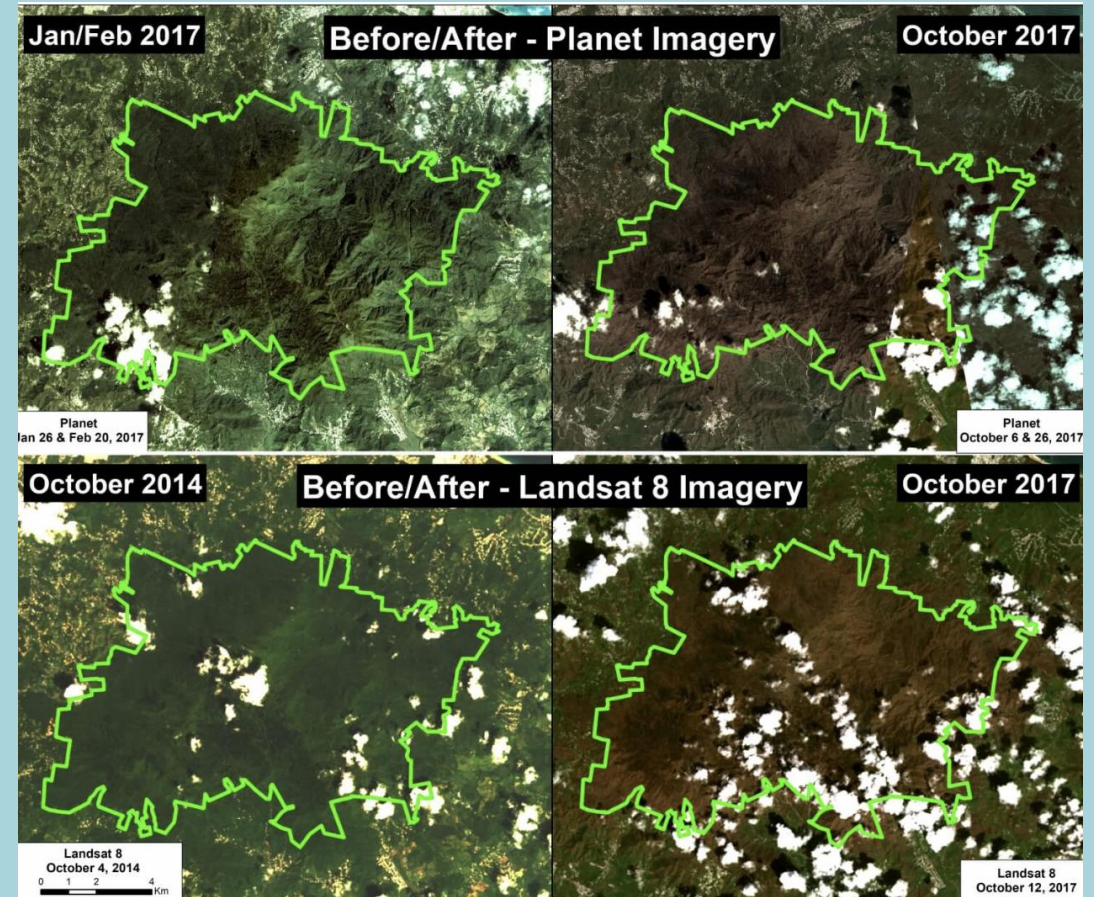
# Caribbean Forests

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- In **1992**, a drought occurred in Puerto Rico, impacting consumption and rationing without lasting effects on the wet forests.
- In **1994-1995**, a severe drought on the island of St. John caused the mortality of **12%** of trees.
- In **2015**, a drought impacted the U.S. Caribbean, reducing the flowering and seed production in the drier Guánica State Forest (Lasky et al., 2016). A period of high leaf fall early during the drought, coupled with a **30%** reduction in the overall growth of trees, was observed (Zimmerman 2020).

# Caribbean Forests

- Research on tropical forestry, ecology, and conservation in Luquillo Mountains in Puerto Rico since the early 19<sup>th</sup> Century has provided insights about resilience to hurricane disturbances; human land use; landslides; drought; and warming, showing that forests can re-establish within 60 years; reversing the paradigm that tropical ecosystems are fragile (Zimmerman et al. 2020, 2021; Gonzalez 2021).

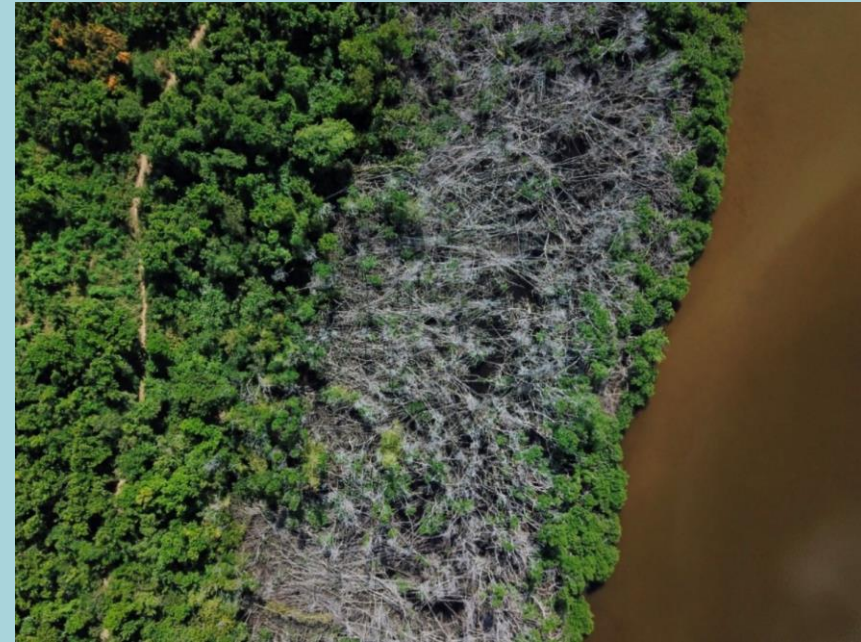


Impact of Hurricane Maria at El Yunque National Forest  
(Obtained from NASA/USGS Landsat 8;  
<https://maaproject.org/2017/elyunque/>)

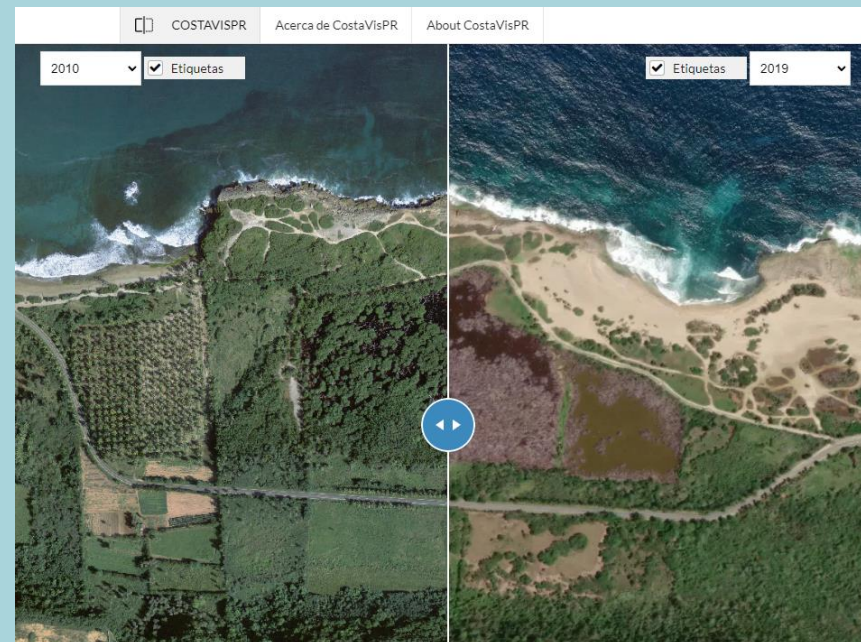
# Mangroves

- Wetlands communities in the US Virgin Islands, including mangroves, comprise only around 2% of total plan communities.
- From 1999 to 2003, satellite images reflected 6,700 ha of mangroves in Puerto Rico (Gould 2007; this estimate depends on the methodology used for the analysis).
- Over the past 50 years, 40 to 50% loss in mangroves has been mainly attributed to land development pressures and natural causes.
- Red mangroves were the more severely affected by hurricanes Irma and Maria.

Sources: PRCCC 2015, 2022



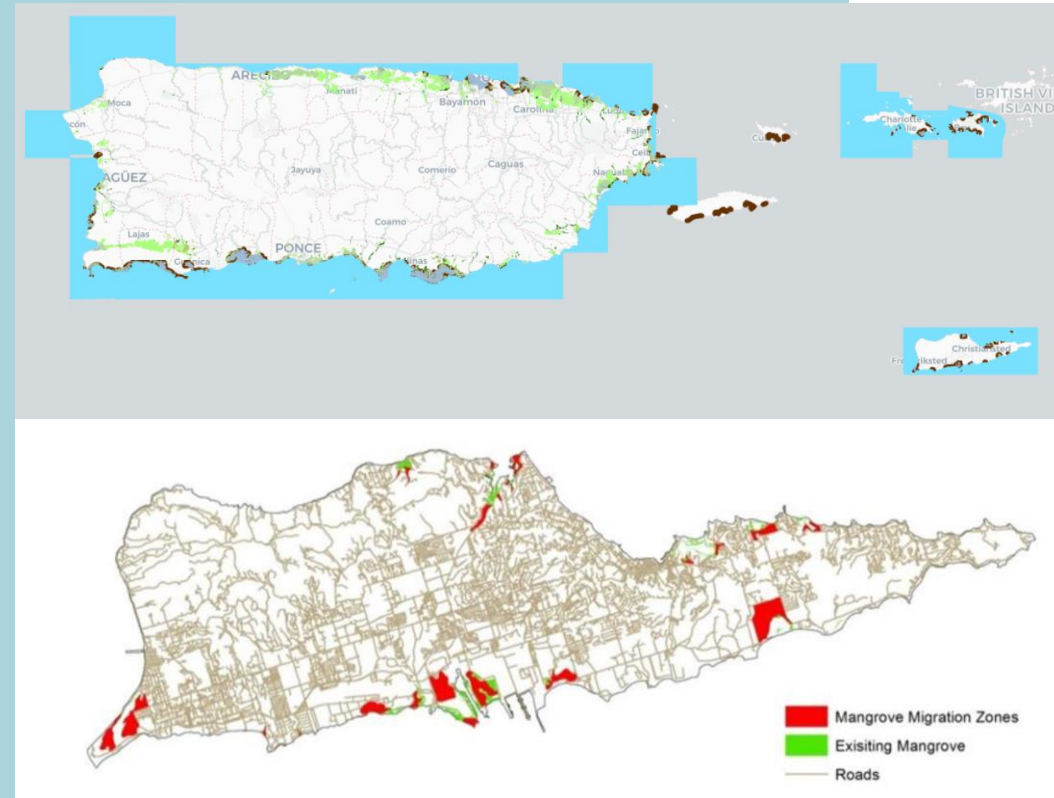
Mangrove mortality from Hurricane Maria – Aguas Prietas Lagoon, Northeast Ecological Corridor Natural Reserve (Source: PRCCC 2022)



Mangrove mortality – Isabela, Puerto Rico (Source: CostaVisPR) 22

# Mangroves

- It is anticipated that rising seas (due to climate change) will affect coastal morphology, causing mangroves to move inland and intrude on dry forests, with consequences for the species that depend on dry forest habitat. Human encroachment prevents the mangrove from moving up to shore.



# Some Highlights

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- In **2014**, estimates of the annual value of commercial fishing of reef fish were **\$9 million** for **Puerto Rico**, **\$2.4 million** for **St. Thomas** and **St. John**, and **\$3 million** for **St. Croix**. (Source: <https://toolkit.climate.gov/regions/economy-0>)
- Coral reefs have an estimated annual economic value of **\$666.4 million** for **tourism and recreation** (Source: Spalding, M., et al. 2017)
- Mangroves have an estimated annual economic value of **\$25.1 million** for **carbon sequestration** (Source: Sanderman, J. et al. 2018)
- Puerto Rico's coral reef-derived tourism generates nearly **\$2 billion in income** (NOAA Coral Reef Conservation Program, 2020).
- El Yunque National Forest represents approximately **20%** of Puerto Rico's tourism economy (U.S. National Forest System).
- Healthy coral reefs can absorb up to **97%** of incoming wave energy, potentially reducing the impacts of storm surges and flooding during a hurricane.



# Thoughts

- Climate change for small islands will become an increasing challenge.
- The level of understanding of the public of climate change and its impacts in the US Virgin Islands and Puerto Rico remains low. The available information should be adapted for all audiences.
- Rehabilitating/restoring damaged ecosystems is essential to future disaster readiness strategies.

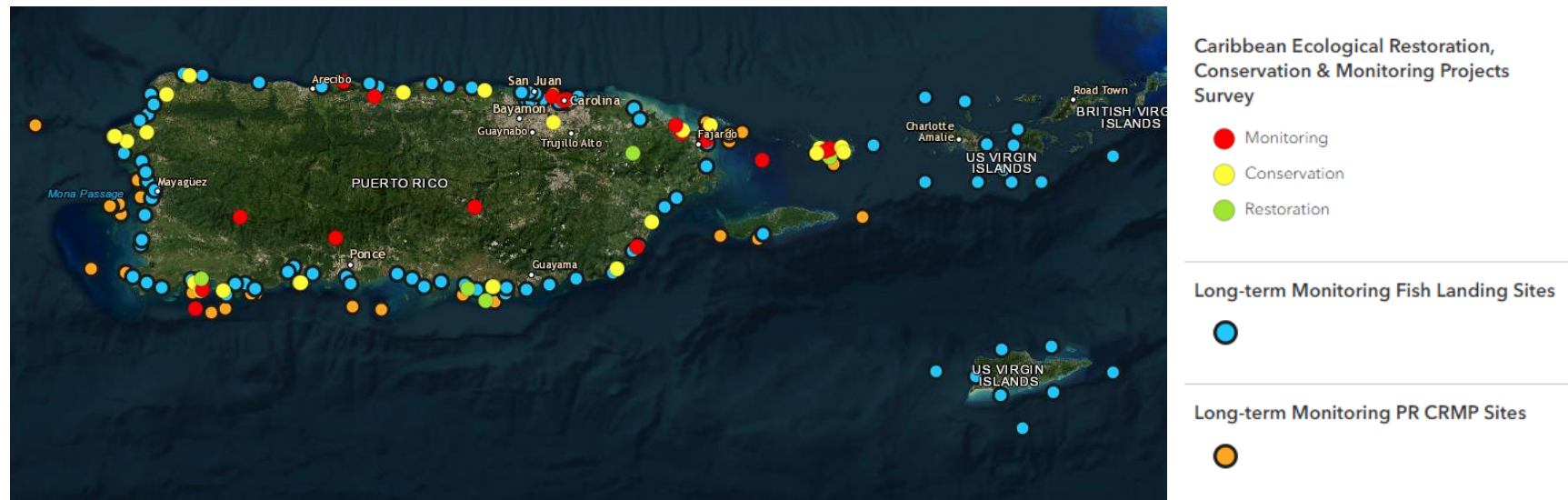




Photo by: Luis Rodríguez

# Thank you!

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