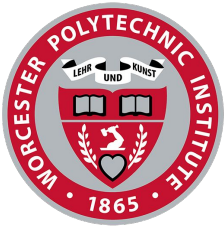


Climate Change Adaptation Strategies for Protected Areas in Puerto Rico

Brooke DePascale, Ari Athair, Jacob Boles, & Dylan Parrow

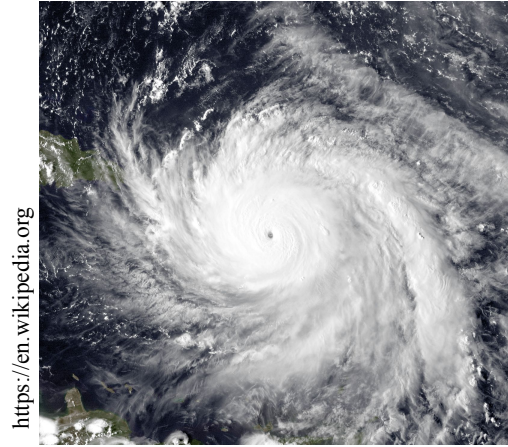


WPI

para la
Naturaleza

Climate Change

- Sea-level rise
- Increased frequency of extreme weather events (hurricanes and monsoons)
- Destruction of ecosystems & infrastructure



Hurricane Maria



Aftermath of Hurricane Harvey



Impacts of Sea-Level Rise

Infrastructure & Habitat

- Coastal erosion
- Increased rate of degradation of organic and inorganic materials
- Direct flood damage
- Partial/Complete Inundation from Sea Level Rise



<https://blog.dhigroup.com>

Examples of Damage to Infrastructure



<https://www.nist.gov>

Sea Level Rise Projections

Projections by 2100

- Low end \approx 0.85 feet
- High end \approx 5.9 foot

Cambers, 2018	<ul style="list-style-type: none">• 1 foot by 2100, 0.16in/year in 21st century
IPCC, 2018	<ul style="list-style-type: none">• 0.85 feet to 2.5 feet by 2100
Ezcurra and Rivera, 2018	<ul style="list-style-type: none">• 2.0 ft by 2050 and 5.9 feet by 2100
Puerto Rico Climate Change Council, 2013	<ul style="list-style-type: none">• 1.6ft to 3.3ft by 2100
Bauzá-Ortega, 2015	<ul style="list-style-type: none">• 0.12in/year in 1990s• Recent studies in Puerto Rico have shown as much as 0.53in/year

Importance

- PLN strives to preserve sites of high ecological value containing infrastructure and cultural heritage sites
- Protection of ecosystems and vulnerable species
- Maintaining tourism industry



What Can Be Done?

Mitigation

- Methods of climate change prevention

Adaptation

- Methods to accommodate climate change



<https://purepng.com>

Adaptation Strategies

Hard Methods



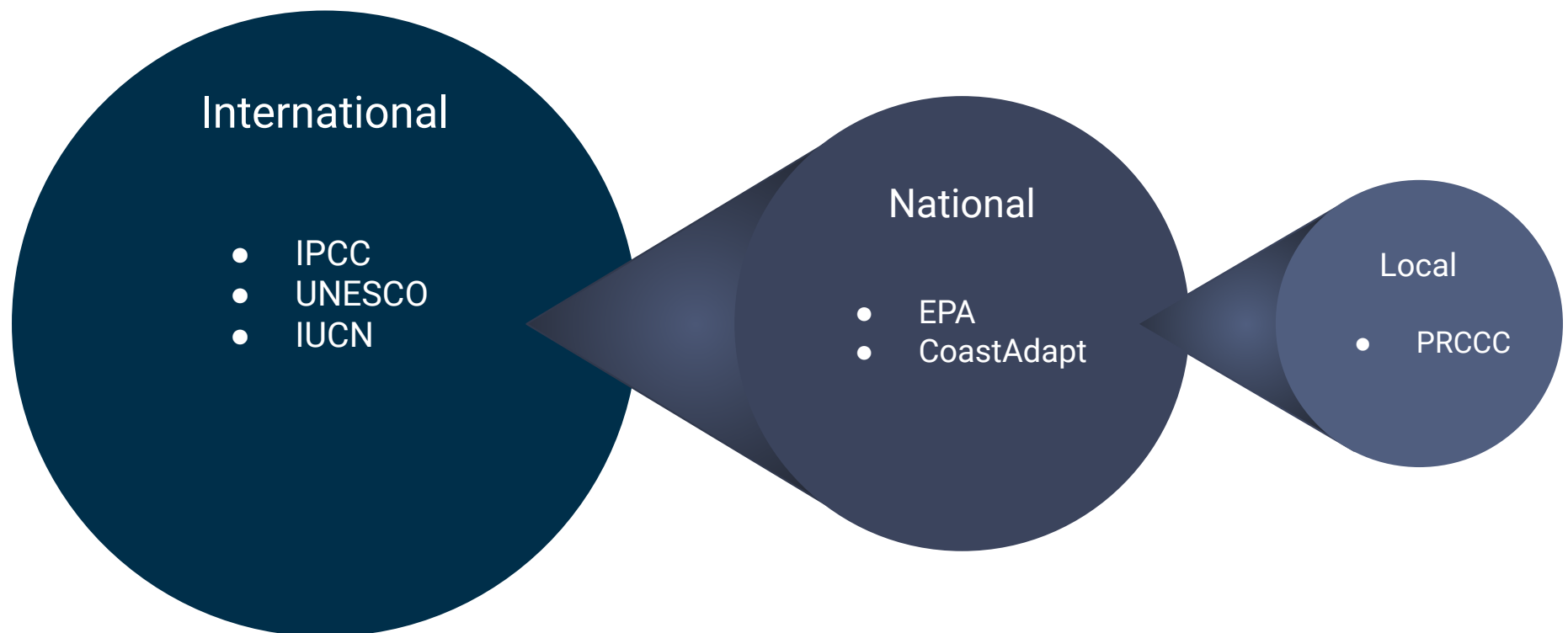
- Building sea walls or jetties
- Fortifying dikes
- Installing breakwaters
- Restoration and replacement of stormwater systems

Soft Methods



- Planting trees and vegetation
- Beach replenishment
- Coral restoration
- Facilitate retreat

Working to Adapt

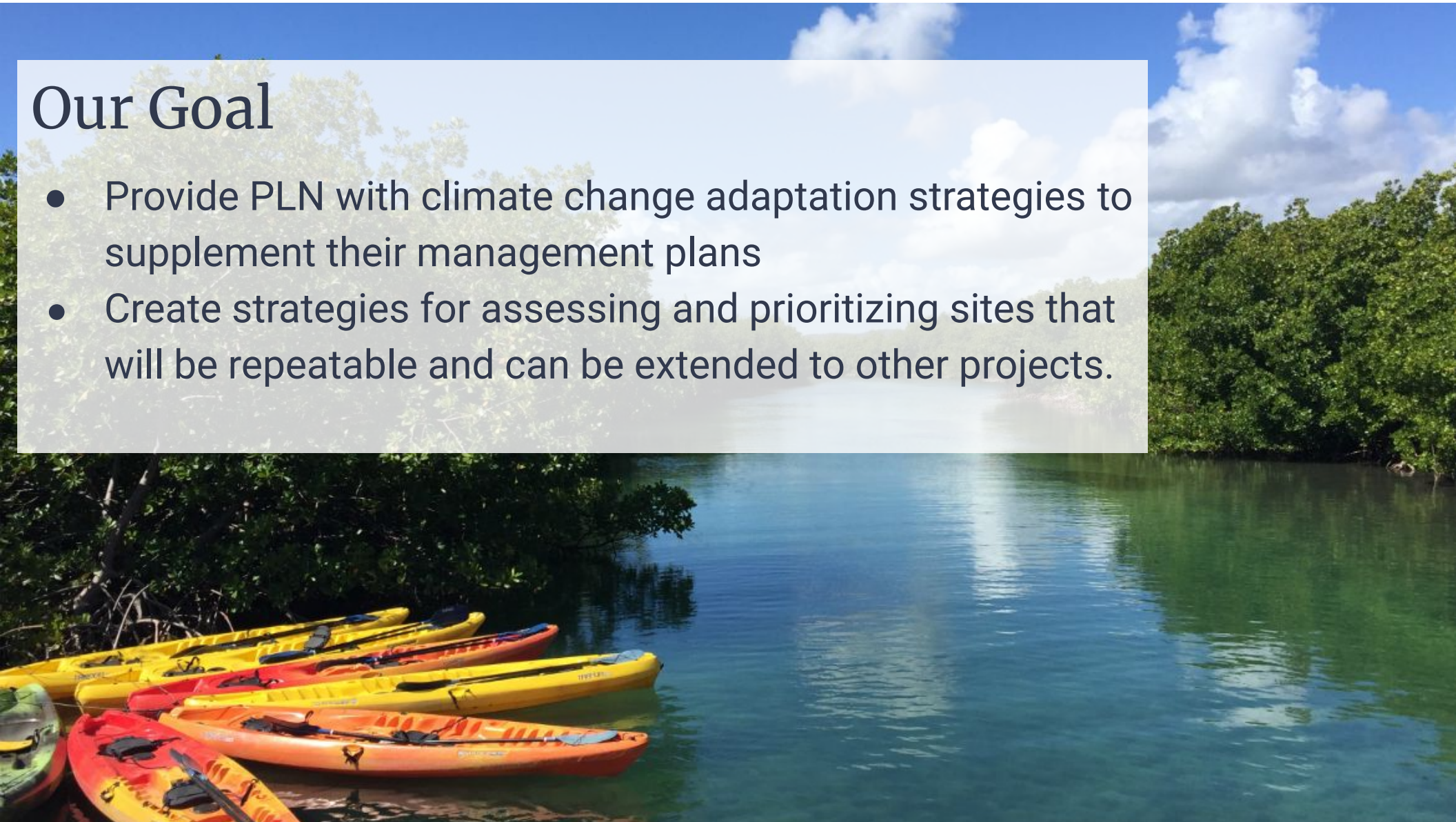


Problems With Existing Methods

- All components required to deliver an effective management plan exist, but they need to be synthesized.
- **Cost Analysis** was often overlooked.
- No existing methods focused on the **challenges** associated with implementing strategies in **protected areas**
 - **Natural, subtle, and non-invasive**

Our Goal

- Provide PLN with climate change adaptation strategies to supplement their management plans
- Create strategies for assessing and prioritizing sites that will be repeatable and can be extended to other projects.





Puerto Rico

Assessment

- Management Plans
- GIS Software
- Employee Interviews
- Site Visits

Prioritization

- Ranking based on importance and vulnerability

Proposal

- Compile Adaptation Strategies
- Cost Analysis

Methodology



15%

1 ft



30%

3 ft



37%

6 ft

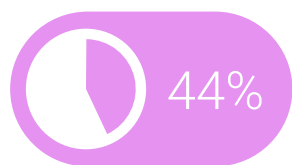
Assessment

Las Cabezas de San Juan Nature Reserve

Site Visit Results

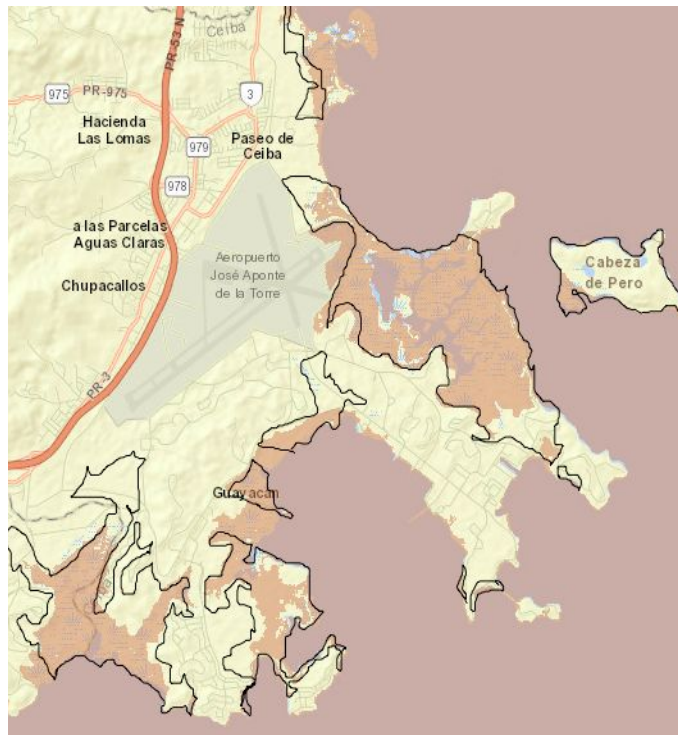


Assessment



44%

1 ft



55%

3 ft



62%

6 ft

Assessment

Área Natural Protegida Medio Mundo y Dagua

Site Visit Results



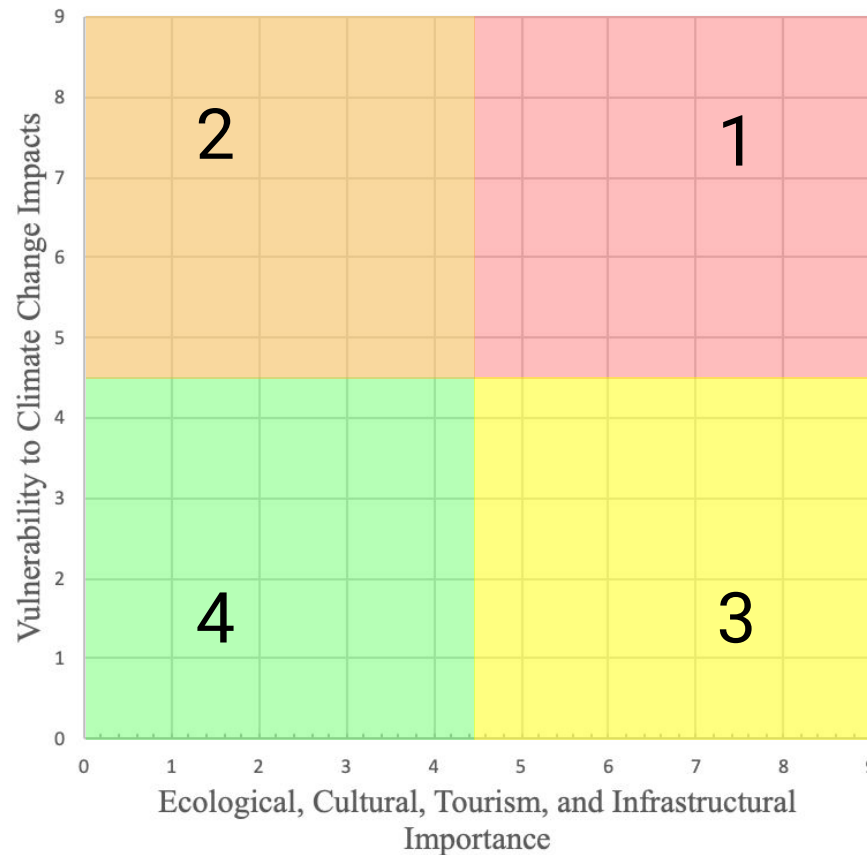
Assessment

Creating a Prioritization Matrix



Vulnerability

- Coastal Erosion
- SLR
- Extreme weather events
- Floodplains



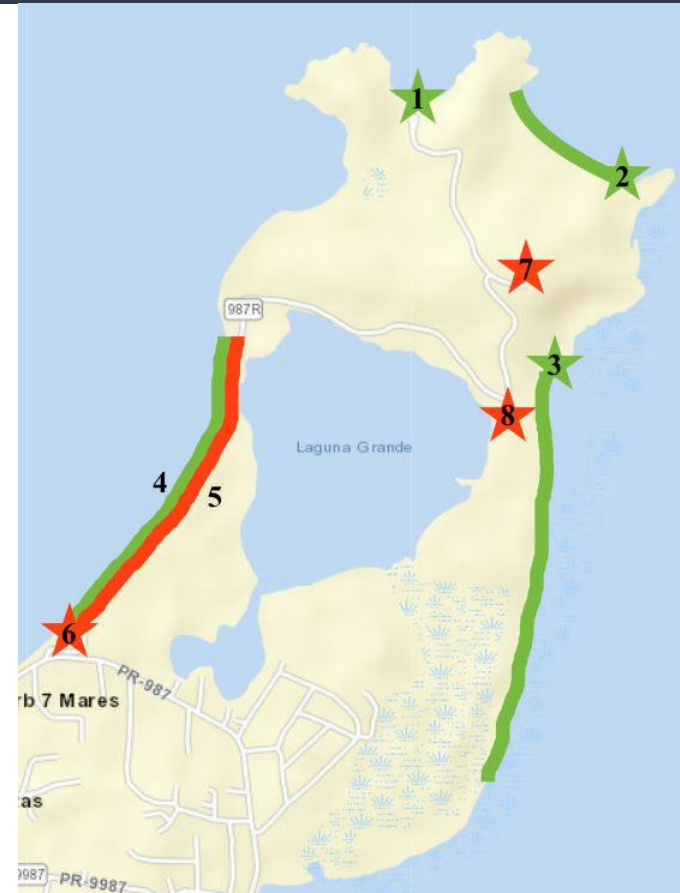
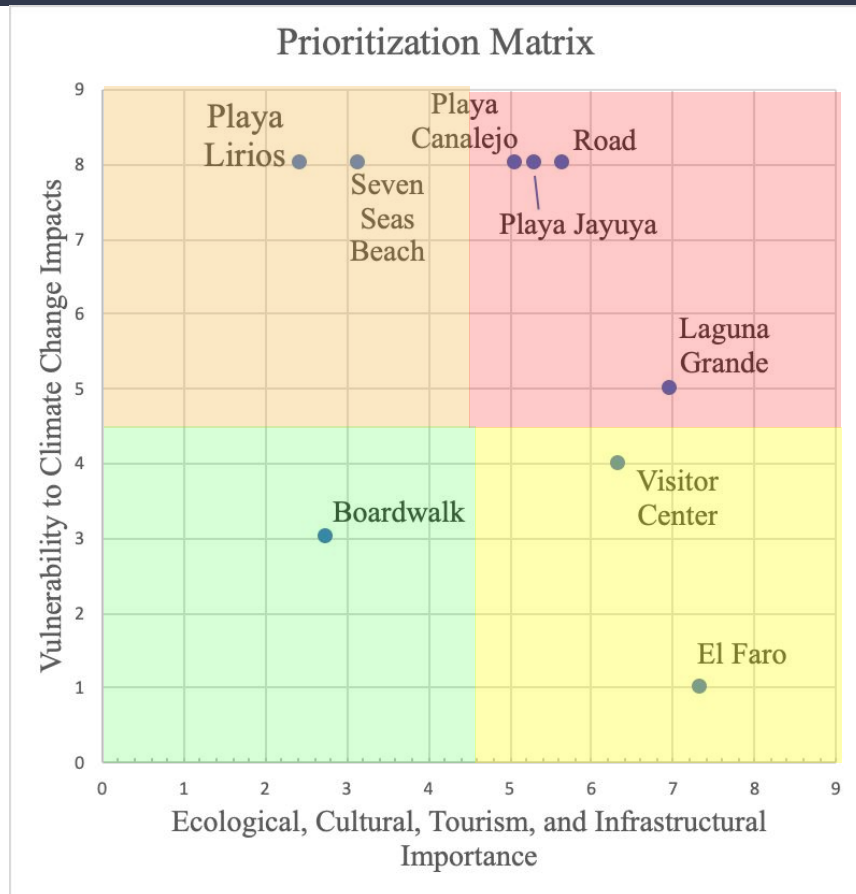
Importance



- Ecological
- Cultural
- Tourism
- Infrastructural

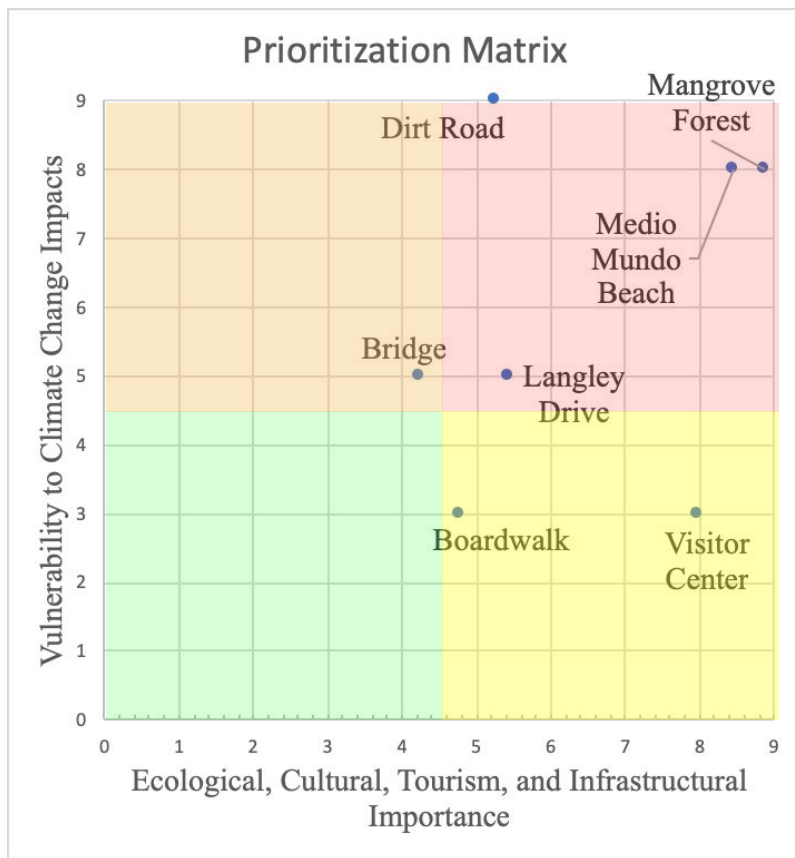
Prioritization

Las Cabezas de San Juan Nature Reserve



Prioritization

Área Natural Protegida Medio Mundo y Dagua



Local Adaptation Considerations

- Any strategies need to be as natural and non-invasive strategies to maintain natural beauty
- Some areas are remote/have limited access
- PLN recognizes that sea level rise may lead to partial or complete inundation of some of their protected areas



Proposal

Las Cabezas de San Juan Nature Reserve Specific Adaptation Strategies

Proposal

Access Road

Elevate Ground
Level in Tree Belt

Potential Loss

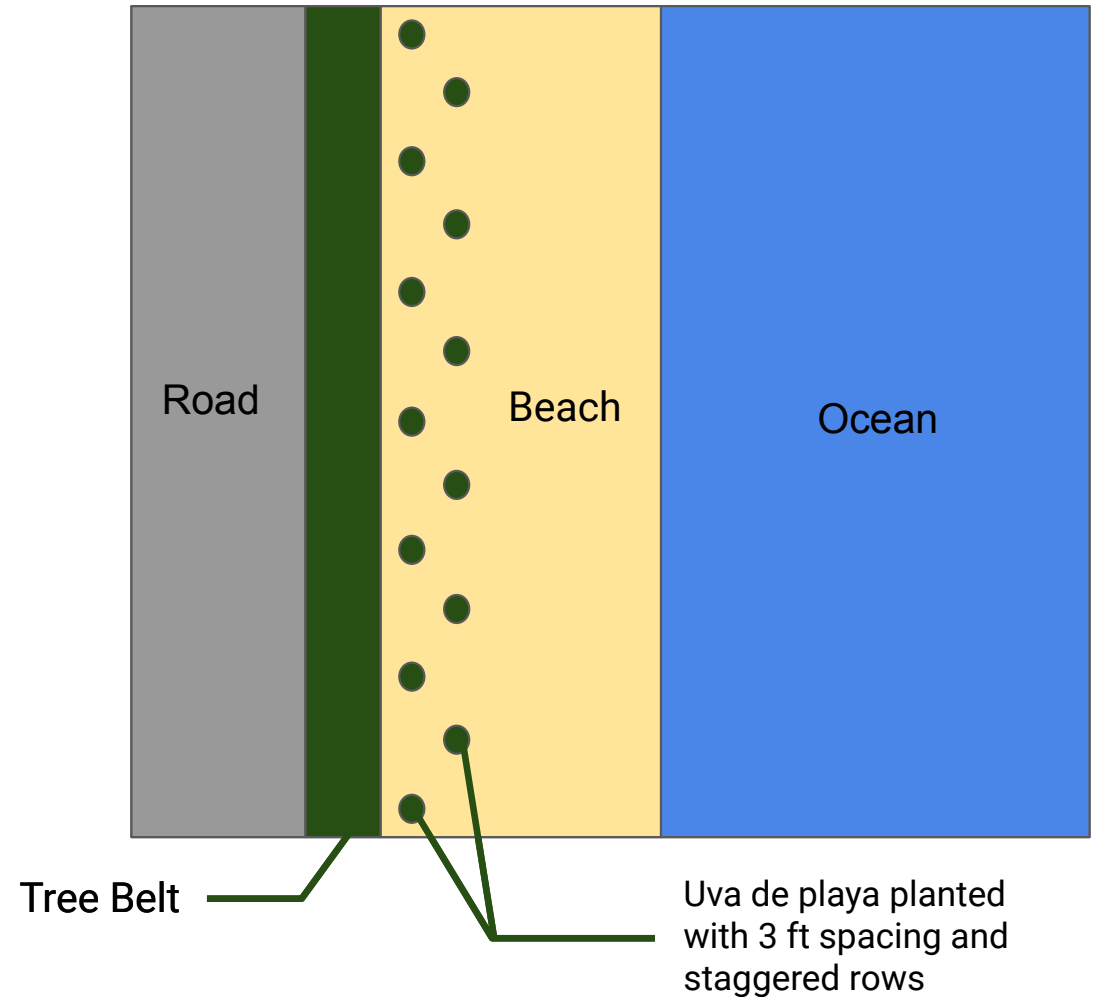


Seven Seas Beach

Beach
Nourishment

Restore Coral

Planting Trees &
Vegetation



Playa Jayuya

Expedite
Excavation Efforts



Playa Canalejo

Coral Restoration

Dune Development

Planting Trees &
Vegetation



Laguna Grande

Future Research to
Address Uncertainty



Playa Lirios

Planting Coral



Visitor Center

Raising
Infrastructure



El Faro

Waterproofing
Infrastructure

Monitor Structural
Integrity



Boardwalk

Raising
Infrastructure



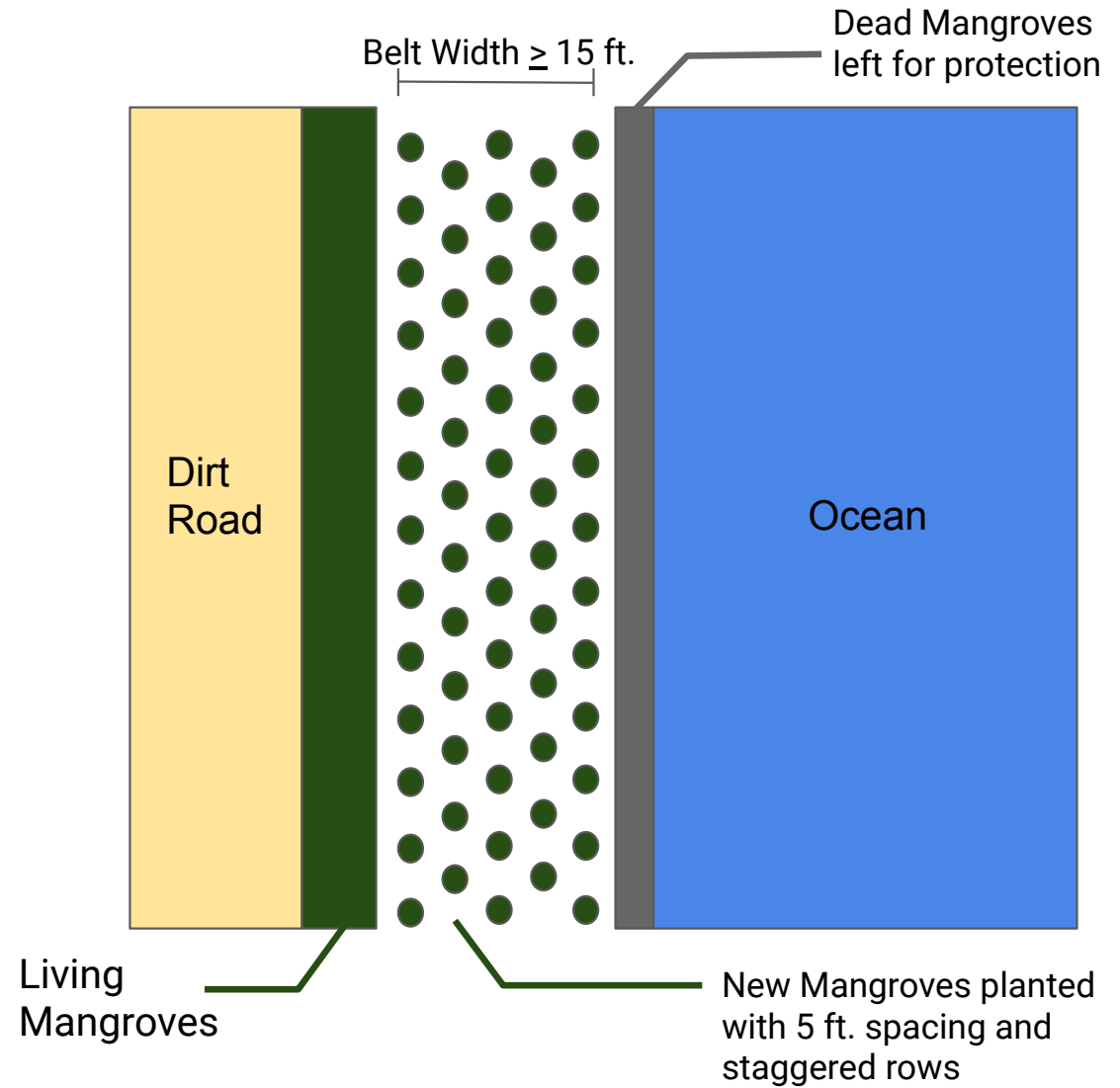
Área Natural Protegida Medio Mundo y Daguaao Specific Adaptation Strategies

Proposal

Coastal Mangroves

Remove Dead Mangroves

Replanting Trees



Dirt Road

Mangrove Belt
Restoration

Reinforcing Road



Medio Mundo Beach

Dune Development

Planting Trees &
Vegetation

Planting Coral



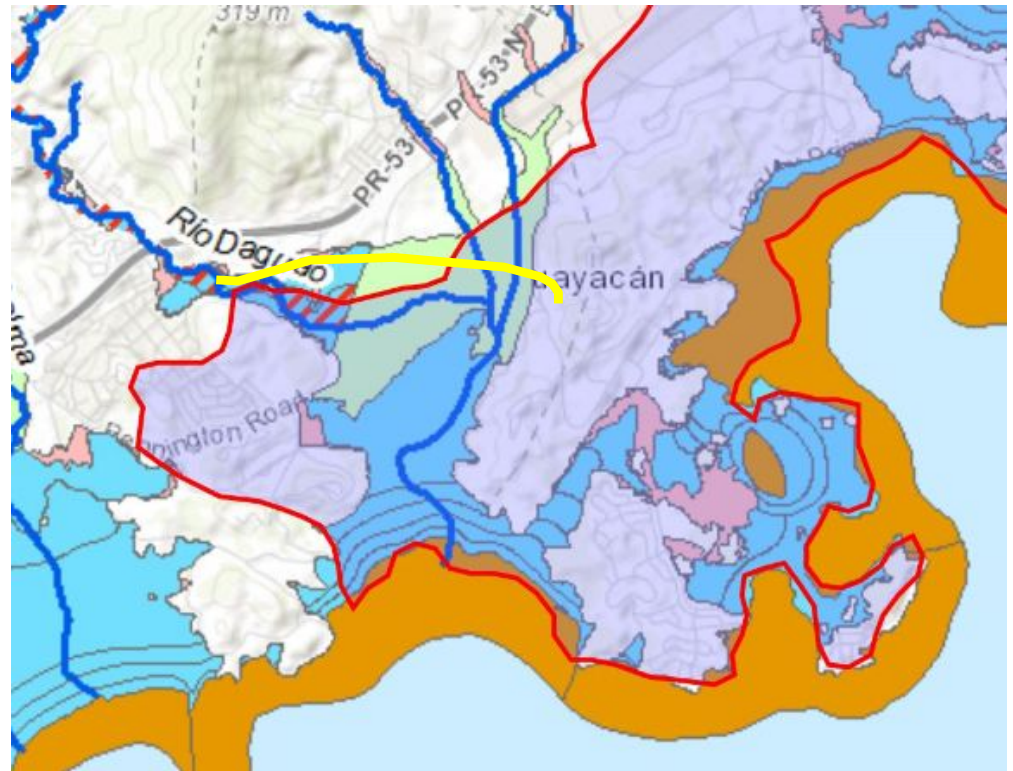
Visitor Center

No action at this time



Langley Drive

Construction of
Levees



Bridge

More Frequent
Replacement

Raising
Infrastructure



Boardwalk

Raising Boardwalk



<https://reservaciones.paralanaturaleza.org>

General Recommendations

- All future planning should consider the effects of climate change
- Establish a system for monitoring the progress of the adaptation methods
- Merge work with other projects and organizations that are to save resources
- Incorporate adaptation into education to raise awareness in local communities

Proposal



Associated Costs

- Estimated costs of implementation
- The cost estimates for each strategy were organized in the form of unit cost
- When applicable, we also estimated the total cost associated with implementing the strategy in a certain area

Special Thanks To...

- Our sponsor, **Para la Naturaleza & Elizabeth Padilla**
- Facilities Coordinator, **Santiago Oliver Báez**
- Environmental Interpreter, **Pablo Ponce De León**
- **Antares Ramos Álvarez**, Regional Superintendent at Para la Naturaleza
- **Soledad Gaztambide Arandes**, Environmental Policy and Government Relations Coordinator
- Production and Planting Manager, **Ahmed Pérez**
- Our professor and advisor, **Professor Nicholas Williams**
- Our School, **Worcester Polytechnic Institute (WPI)**

References

- Australian Government Department of the Environment and Energy. (2019). Climate change. Retrieved January 12, 2019, from <http://www.environment.gov.au/climate-change>
- Bruin, K., Dellink, R., Ruijs, A., Bolwitt, L., Buuren, A., Graveland, J., . . . Ierland, E. C. (2009). Adapting to climate change in The Netherlands: An inventory of climate adaptation options and ranking of alternatives. *Climatic Change*, 95(1-2), 23-45. doi:10.1007/s10584-009-9576-4
- Climate Adapt. (2015, September 1). Dune construction and strengthening (2015). Retrieved from https://climate-adapt.eea.europa.eu/metadata/adaptation-options/dune-construction-and-strengthening/#costs_benefits
- Eastern Research Group. (2013). What will adaptation cost? An economic framework for coastal community infrastructure. *Final Report, National Oceanic and Atmospheric Administration* (NOAA) Coastal Service Center.
- Ezcurra, P., & Rivera-Collazo, I. 2018. An assessment of the impacts of climate change on Puerto Rico's cultural heritage with a case study on sea-level rise. *Journal of Cultural Heritage; Journal of Cultural Heritage*, 32, 198-209. doi:10.1016/j.culher.2018.01.016
- FEMA. (2007, March). *Selecting Appropriate Mitigation Measures for Flood-prone Structures*(Rep.). Retrieved April 18, 2019, from FEMA website: https://www.fema.gov/media-library-data/20130726-1609-20490-5083/fema_551.pdf
- Government of Puerto Rico. (2015, December 10). Interactive Map of Puerto Rico [Computer software]. Retrieved March 13, 2019.
- Gov tells global tourism industry about Puerto Rico’s potential as a tourism, investment destination. (2019, Jan 29.). *Caribbean Business*, Retrieved from <https://caribbeanbusiness.com/gov-tells-global-tourism-industry-about-puerto-ricos-potential-as-a-tourism-investment-destination/>
- International Union for Conservation of Nature. (2019, March 22). About. Retrieved from <https://www.iucn.org/about>
- NCCARE. (2019). CoastAdapt. Retrieved February 3, 2019, from <https://coastadapt.com.au/>
- NOAA Office for Coastal Management. (n.d.). DigitalCoast. Retrieved February 6, 2019, from <https://coast.noaa.gov/digitalcoast/tools/slr>
- Para la Naturaleza - who are we? Retrieved from <https://www.paralanaturaleza.org/en/who-are-we/>
- Prioritization matrix: QI toolbox. (n.d). Retrieved from <http://www.health.state.mn.us/divs/opi/qi/toolbox/prioritizationmatrix.html>
- Puerto Rico Climate Change Council. (2013.) Puerto Rico’s state of the climate 2010-2013: Assessing Puerto Rico’s social-ecological vulnerabilities in a changing climate. Puerto Rico Coastal Zone Management Program, Department of Natural and Environmental Resources, NOAA Office of Ocean and Coastal Resource Management. San Juan, PR.
- Rashband, W. (2018, July 11). ImageJ [Computer software]. Retrieved from <https://imagej.nih.gov/ij/download.html>
- Responding to climate change. (2019). Retrieved from <https://climate.nasa.gov/solutions/adaptation-mitigation/>
- Restoration of Seagrass Meadows. (n.d.). OCEANA. Retrieved from https://www.saveposidoniaproject.org/formentera/wp-content/uploads/2017/03/OCEANA_Restoration_of_seagrass_meadows.pdf
- Spurgeon, J. (2001). Improving the economic effectiveness of coral reef restoration. *Bulletin of Marine Science*, 69, 1031-1045.
- Synthesis of Adaptation Options for Coastal Areas (2009). Washington, D.C.: U.S. Environmental Protection Agency, Office of Air and Radiation, Office of Water. Retrieved from https://www.epa.gov/sites/production/files/2014-04/documents/cre_synthesis_1-09.pdf
- The Commonwealth of Massachusetts. (2018, December). *StormSmart Properties Fact Sheet 6: Sand Fencing*(Rep.). Retrieved April 19, 2019, from The Government of Massachusetts website: <https://www.mass.gov/files/documents/2018/05/29/ssp-factsheet-6-sandfencing-new.pdf>
- Tompkins, E., & Adger, W. (2004). Does adaptive management of natural resources enhance resilience to climate change? *Ecology and Society*, 9(2). Retrieved from <http://www.jstor.org/stable/26267677>
- U.S. EPA (2009). *Synthesis of adaptation options for coastal areas*. Washington, D.C.: U.S. Environmental Protection Agency, Office of Air and Radiation, Office of Water. Retrieved from https://www.epa.gov/sites/production/files/2014-04/documents/cre_synthesis_1-09.pdf

Questions?