# VULNERABILITY OF THE MEXICAN CARIBBEAN BEACHES

Laura R. de Almeida, Instituto de Ingeniería UNAM lribasa@iingen.unam.mx
Izchel Gómez, Instituto de Ingeniería UNAM, izchel_rom@comunidad.unam.mx
Itxaso Odériz, Instituto de Hidráulica Ambiental, Universidad de Cantabria, itxaso.oderiz@unican.es
Mónica Pedraza Buitrago, Instituto de Ingeniería UNAM, mpedrazab@iingen.unam.mx
Ismael Mariño-Tapia, ENES-Mérida UNAM, imarino@enesmerida.unam.mx
Rodolfo Silva, Instituto de Ingeniería UNAM, rsilvac@iingen.unam.mx

## INTRODUCTION

The Mexican Caribbean is a high-risk coastal area. It faces numerous natural and anthropogenic hazards due to its unique ecosystem worldwide and significant economic pressure in the region. The area, which have a high population density in cities like Cancún, Playa del Carmen and Tulum, have been affected by accelerated changes altering its natural dynamics (Silva et al, 2019). These alterations have led to the instability and degradation of the coastal ecosystems (Silva et al, 2019), resulting in the reduction of protection services provided by coral reefs and coastal vegetation against hurricanes, a phenomenon widely demonstrated (Odériz *et al*, 2020).

Based on the definition of vulnerability proposed by the Intergovernmental Panel on Climate Change (IPCC): "vulnerability is the propensity or predisposition of the environment, people, or property to a specific hazard, encompassing several elements and concepts, such as sensitivity or susceptibility to damage and lack of adaptive capacity" (IPCC, 2019). We can state that the degradation of ecosystems is directly related to the loss of ecosystem services, which, in turn, increases vulnerability (Peng *et al,* 2023).

This study performed a spatial vulnerability analysis of the Mexican Caribbean coast by analyzing vulnerability indicators based on geomorphological (sediment and beach characteristics) and biological (foredune, seagrass, and coral reef cover) factors. Based on the spatial analysis, the areas of higher vulnerability in the region were identified. Once these vulnerable areas are identified, it is possible to identify adaptation and mitigation strategies to mitigate climate risk.

## METHODS

In pursuing this goal, the coastline was characterized by considering the type of 35 beaches (sampled in October 2022), the presence of seagrass meadows and coral reefs (CONABIO/UNAM, 2018), and the classification of foredunes (de Almeida *et al*, 2022) along the Mexican Caribbean region (Fig. 1). The main function to consider was the reduction of the wave energy that each element contributes to the system in a extreme event (e.g. hurricanes). The drag coefficient was used for vegetation and the presence of coral reefs. The drag coefficient measures the resistance to the flow of a fluid (the wave) over a solid body (e.g., the coral reefs, Bosboom & Stive, 2023). A higher drag coefficient indicates a greater decrease in wave energy and, consequently, a lower vulnerability. On the contrary, a lower drag coefficient indicates a smaller decrease in wave energy and, consequently, greater vulnerability.

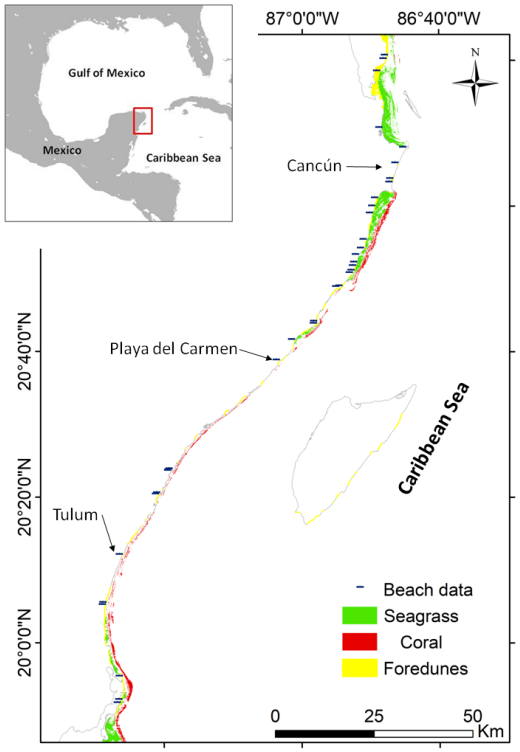


Figure 1 – Study Area in Mexican Caribbean and the data used (beaches, seagrass, coral and foredune cover).

Regarding beach type, they were ranked according to the sediment characteristics, since they can provide information about morphodynamic (Alcérreca-Huerta *et al*, 2022) and then indicate different degrees of vulnerability.

To calculate the vulnerability coefficients, indices are also used based on the significance of the variables of the beaches and each adjacent ecosystem that directly influence the beach. Some variables include the area covered by ecosystems, the depth and distance from the coast of ecosystems, and the level of anthropization in the area. Finally GIS techniques was applied to compose vulnerability map.

## RESULTS

A regional map of vulnerability to climate hazards has been developed, which provides a holistic criterion for

coastal management in the region.
The results exhibit that Cancún lacks a protective balance from various ecosystems. Cancún is characterized by larger foredunes and the absence of coral reefs or seagrass meadows. All its ecosystem service depends on the foredune, which has been significantly damaged due to the construction of anthropic structures, as Figure 2 shows.

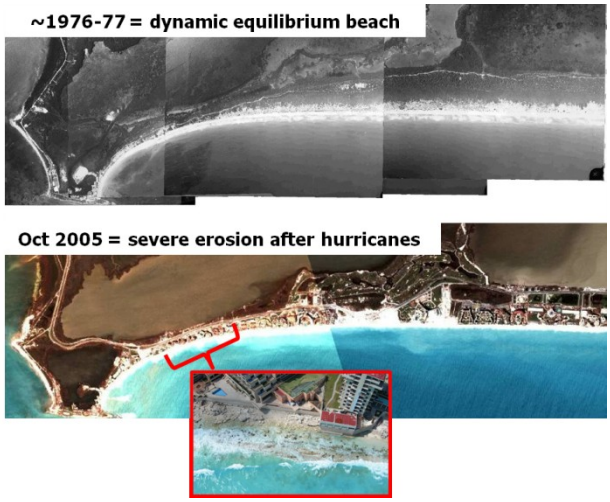


Figure 2 – Example of a very vulnerable beach affected by hurricanes (Cancun) due to the loss of the foredunes ecosystem

## CONCLUSION

The proposed analysis allows identifying the most vulnerable areas and this methodology may be used to evaluate changes in this vulnerability due to the possible degradation of coastal ecosystems. This leads to priority areas for ecosystem restoration projects, which can lead to a recovery of their environmental services andmitigate environmental risk.

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