

Mangroves for Coastal Protection: Evidence from Hurricanes in Central America

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Efficient coastal defense is increasingly important for policy

Growing economic activity in coastal areas (more in harm's way)

Climate change entail more frequent high-intensity storms

→ Adaptation

- Save lives
 - early warning systems
- Protect assets and economic activity
 - built infrastructure (e.g., seawalls and breakwaters)
 - natural habitats (corals reefs, seagrass meadows, and mangrove forests)

Mangroves can provide protection against storms

Mangrove forest can reduce:

- Storm surge (Krausset al., 2009; Barbier et al., 2011; Zhang et al., 2012; Liu et al., 2013)
- Wind and swell waves (Massel et al., 1999; Mazda et al., 2006; Barbier et al., 2008; Horstman et al., 2014)
- Wind speed (Das and Crépin, 2013)



Figure: *Rhizophora mangle*

Research Question: Can mangroves reduce the impact of hurricanes on local economic activity?

What we do: *We provide the first empirical estimates of the value of mangroves in terms of protecting economic activity from hurricanes.*

- Estimate the the disruption to economic activity generated by hurricanes that made landfall in Central America between 2001-2013
- Explore the heterogeneity in the impact of hurricanes with respect to initial mangrove protection (mangrove width in 2000)

Nightlight intensity as an indicator of local economic activity

The economic impact of hurricanes has been shown to be highly localized (e.g., Bertinelli and Strobl, 2013; Elliott et al., 2015)

Nightlights have been extensively used to measure local economic wealth (e.g., Chen and Nordhaus 2011; Henderson et al., 2011; Bertinelli et al., 2016)

We use annual nightlight composites produced by NOAA (~ 1 km² cells)

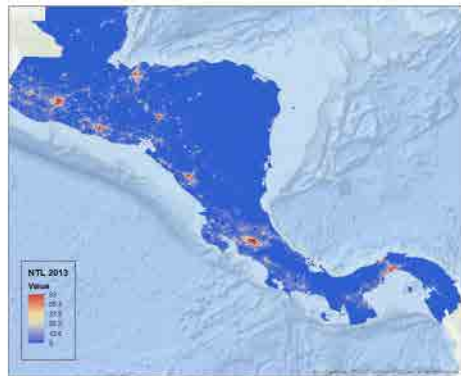


Figure: Nightlight imagery of Central America, year 2013

Converting wind speed into potential damage

Wind Field Model (Pita et al., 2015)

- Based on the asymmetric Holland equation and calibrated for Central America
- Maximum wind speeds (km/h) ($\sim 1 \text{ km}^2$ cells)

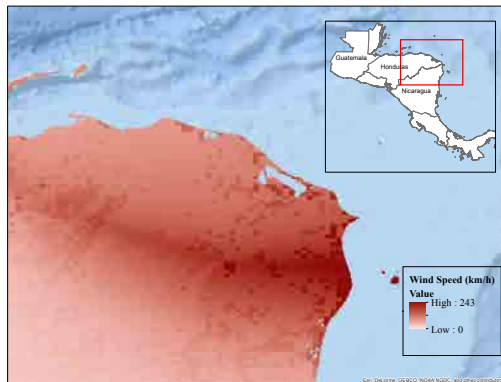


Figure: Hurricane Felix, year 2007

Converting wind speed into potential damage

To translate wind speed into potential destruction we use the damage function proposed by Emanuel (2011).

Damage Index, f

$$f_{it} = \frac{\left[\frac{\max(V_{it} - V_T, 0)}{V_h - V_T} \right]^3}{1 + \left[\frac{\max(V_{it} - V_T, 0)}{V_h - V_T} \right]^3} \quad (1)$$

V_{it} is wind speed in cell i and year t , V_T is the damage threshold (93 km/h), and V_h is when half of all structures are expected to be destroyed (278 km/h).

Impact of hurricanes on nightlights

	(1)	(2)	(3)
f	-4.055 (1.693)	-4.046 (1.765)	
$f(t-1)$		0.104 (1.543)	
f in non-storm surge prone areas			-2.574 (6.648)
f in storm surge prone areas			-4.417 (0.648)

Note: Total obs: 2,757,001 (storm surge prone area 100,854). All regressions include cell and year fixed effects. Clustered standard errors at the municipal level in parentheses.

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Example: A category 3 hurricane (208 km/h) $\Rightarrow f \approx 0.2$,
decreases nightlights by 0.81 units (4.055×0.2) or by 15.9%
(0.81/5.1)

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No evidence of long-term effects

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Example: A category 3 hurricane (208 km/h) $\Rightarrow f \approx 0.2$,
decreases nightlights in storm surge prone area by 0.88 units
(4.417×0.2) or by 17.3% ($0.88/5.1$)

Measure of forest protection: the width of mangrove on the path to the coast

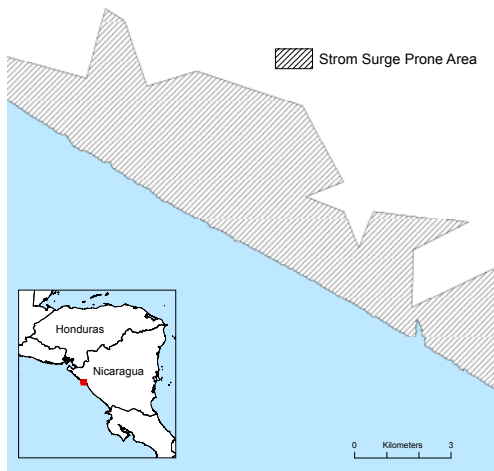


Figure: State of Leon, Nicaragua

Measure of forest protection: the width of mangrove on the path to the coast



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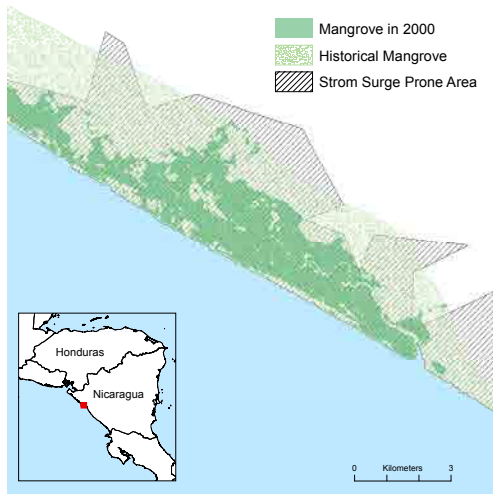


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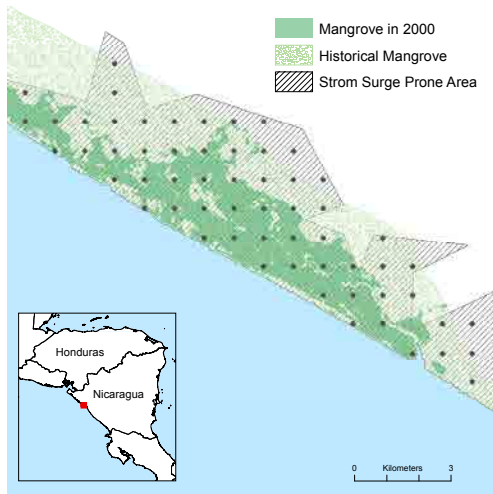


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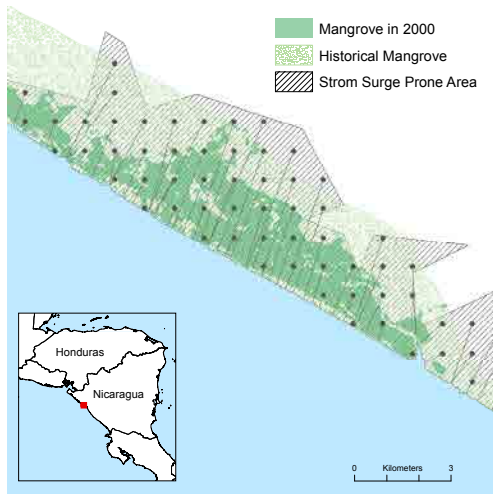


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