The effect of fragmentation on forest damage caused by hurricane Dean (2007) in the Mexican Yucatán

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Introduction

Fragmented forests are likely more vulnerable than continuous forest to the impacts of large wind disturbances, such as hurricanes, for two reasons (Laurence and Curran 2008):

1) cleared lands allow for accelerated wind speeds as they provide less resistance, and
2) fragmentation results in an increase in the proportion of abrupt forest edges, which are exposed to the direct effects of winds.

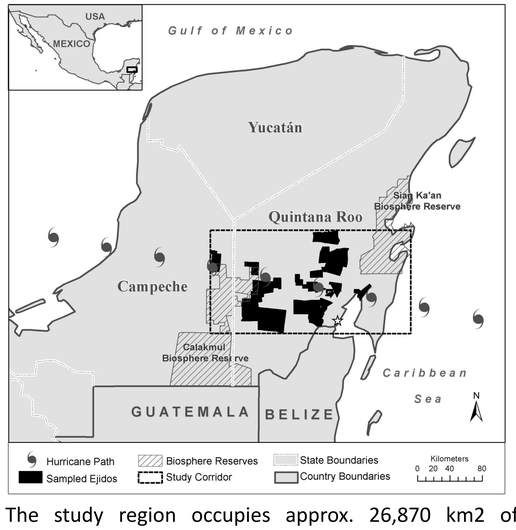
Understanding the synergies between forest fragmentation and wind disturbances at the landscape scale is particularly important because land management decisions and policies that result in land use and land cover changes, which cause fragmentation, are implemented at this scale (Turner et al. 2007).

This research is very relevant for the seasonal forests of the Yucatán Peninsula, the largest expanse of mature forest remaining in Mexico. In addition to increasing anthropogenic impacts (Lawrence et al. 2004), these forests have been struck by more than 60 hurricanes in the past 150 years (Boose et al. 2003).

Objective

To characterize forest fragmentation in the Sian Ka'an – Calakmul biological corridor between 1976 and 2010, and examine the relationship between current forest fragmentation status and the damage caused by hurricane Dean in 2007, in the context of the predominant land management units (*ejidos*).

Study Area



The study region occupies approx. 26,870 km2 of southern Quintana Roo and southeastern Campeche, near the Mexico–Guatemala border. Vegetation is characterized by a mosaic of seasonally dry medium-statured forests (selva mediana) and low-statured forests (selva baja or bajos). The north-western path followed by hurricane Dean (August 2007) is shown.

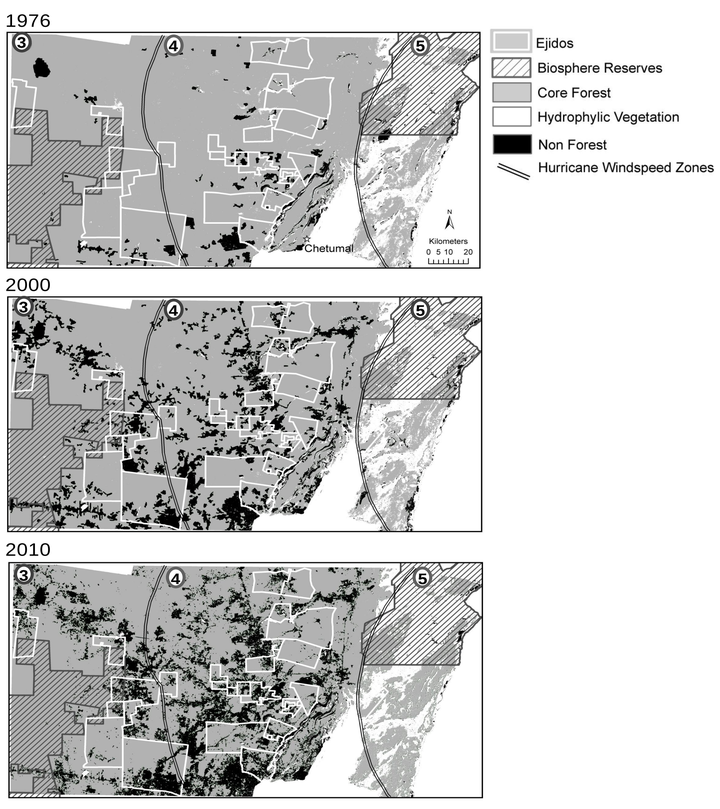
Methods

Land cover maps for 1976, 2000 and 2010 were used to characterize forest fragmentation 34 years. The maps were reclassified to binary forest vs. non forest maps, and a morphological spatial pattern analysis (MSPA) was applied to each map using the Guidos 1.3 software (Vogt 2010). Five different indicators derived from MSPA were used to assess the patterns in forest fragmentation : *% core, % perforated, % bridge, % islet, % edge and edge/core ratio*.

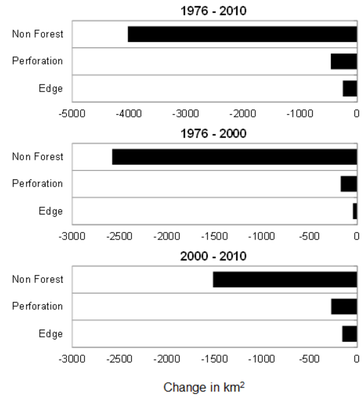
To measure the correlation between forest fragmentation and forest damage caused by hurricane Dean, a pairwise correlation analysis between the fragmentation indicators from the MSPA and a regional hurricane damage map (Rogan et al. 2011) was conducted at the *ejido* level for the entire region.

Forest Fragmentation in the Sian Ka'an – Calakmul corridor 1976 – 2010

Forest fragmentation in the Sian Ka'an – Calakmul biological corridor.



Main contributors to losses in *core* forest between 1976 and 2010.

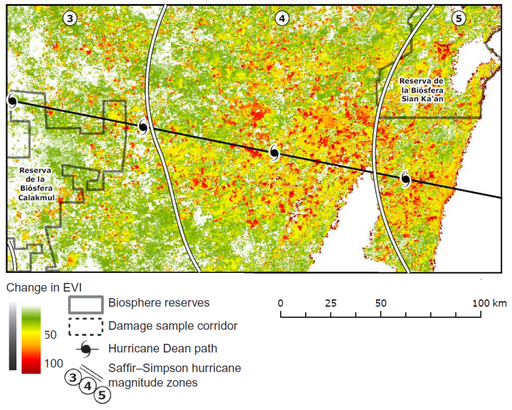


Change in forest extent and fragmentation indicators within the Sian Ka'an – Calakmul biological corridor between 1976 and 2010.

	1976	2000	2010
Extent of all Forest (km²)	22,782	20,182	18,738
Percent of study area	87.7%	77.7%	72.1%
Fragmentation indicators (% of forest)			
Proportion Core	99.45	98.38	95.46
Proportion Perforation	0.26	1.09	2.70
Proportion Bridge	0	0	0.01
Proportion Islet	0	0	0.03
Proportion Edge	0.55	1.62	4.52
Edge/Core Ratio	0.01	0.02	0.05

Hurricane Dean Forest Damage Map

MODIS 1 km Enhanced Vegetation Index (EVI) map of vegetation damage caused by Hurricane Dean (Rogan et al. 2011)



Forest fragmentation and hurricane damage

Pairwise correlations of the fragmentation indicators and the average hurricane damage for the *ejidos* of the study area. Similar results were obtained for the total damage per *ejido*.

	Average Forest Damage	
	Wind speed Zone4 (N=114)	
Fragmentation Indicator	**β Coefficient**	**Prob>|t|**
Proportion Core	-0.2718	0.0004*
Proportion Islet	0.2730	0.0004*
Proportion Perforation	-0.1665	0.0326*
Proportion Bridge	0.1575	0.0433*
Proportion Edges	0.2711	0.0004*
Edge/Core Ratio	0.2732	0.0004*

Main Findings

- At least 4,000 km² of forest was lost between 1976 and 2010 (approximately 18% of the 1976 forest).
- The rate of deforestation over 34 years is (0.52%). Rates of deforestation for *core forest* were higher than for all forest (by 10%).
- MSPA results show a 4% decrease in the *proportion of core forest* and a 4% increase in the *proportion of edge* forest. All other fragmentation indicators increased through time to a smaller degree.
- The loss in forest extent within the study area is congruent with previous studies that have identified Mexico, and in particular its southern tropical forests, as a deforestation 'hot spot'.

Synergies between hurricane damage and forest fragmentation

Hurricane Dean severely impacted the forests of the Sian Ka'an – Calakmul biological corridor. A plot-level study reported wind-damage to most trees (72%), including stem snapping, branch damage, uprooting and death (Vandecar et al. 2011). An analysis of remotely-sensed data pre- and post-storm suggests significant forest damage in 83% of the region (Rogan et al. 2011).

Our results show that forest fragmentation plays a statistically significant role in explaining the presence and pattern of hurricane damage as the *ejido* analysis reveals significant relationships between fragmentation indicators and hurricane damage within the corridor. These results support the hypothesis that fragmented forests are more vulnerable to wind storms at the landscape scale.

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Acknowledgements

This research was supported by the Gordon and Betty Moore Foundation under Grant #1697. Special thanks to Birgit Schmook and Maria Manzon.

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