Hurricane Impacts to Puerto Rico's Forests

The Importance of Topography and Chance

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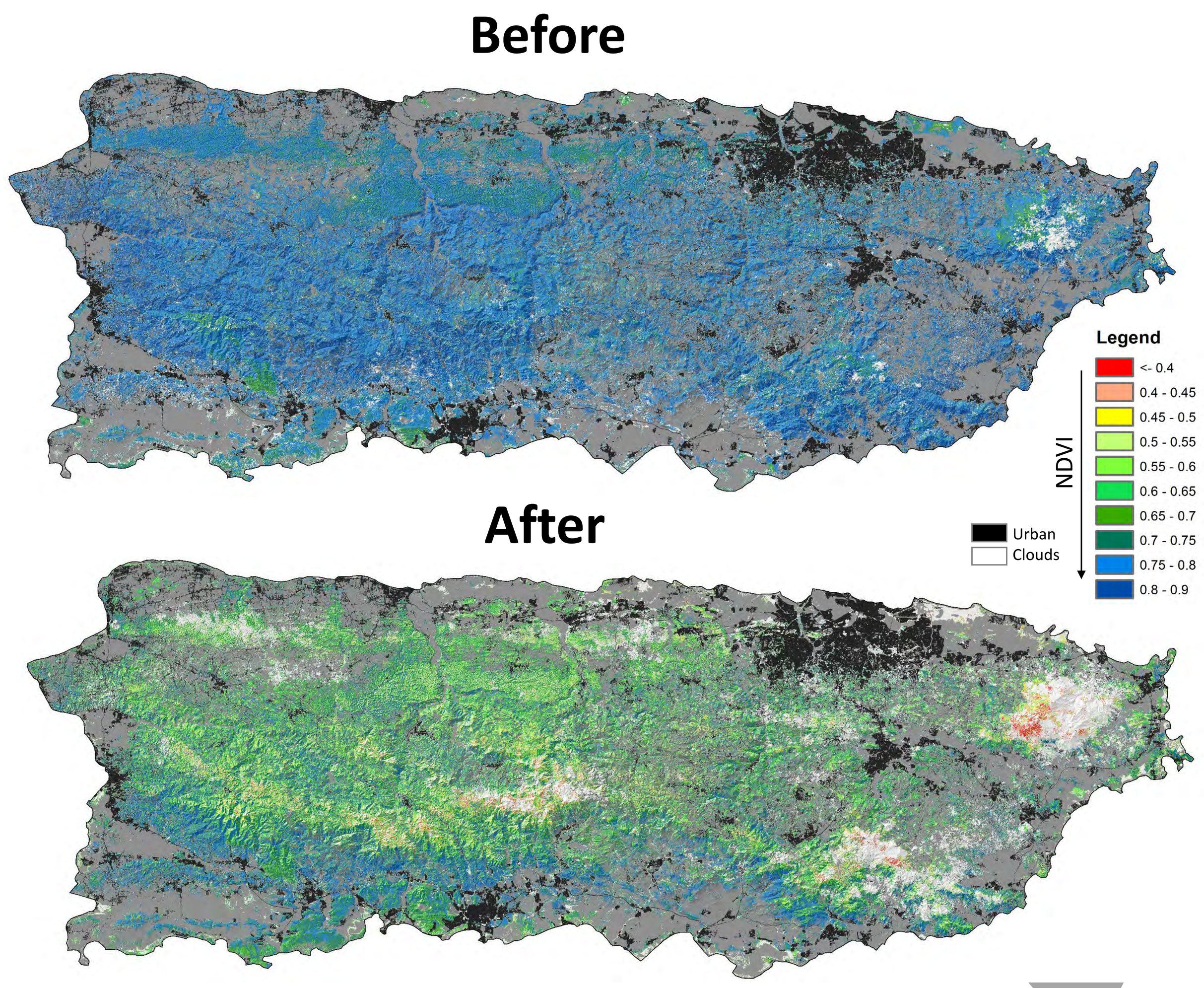


INTRODUCTION

Predictions of increased hurricane intensity suggest that Caribbean forests may experience more impacts in the future. The risks of such events were demonstrated on Sept. 20, 2017 when Hurricane Maria struck Puerto Rico as a Category 4 storm just 14 days after Hurricane Irma (a Category 5 storm) passed just 97 km north of the island without making landfall. These back-to-back hurricanes caused a severe humanitarian crisis and widespread damage to the island's forests.

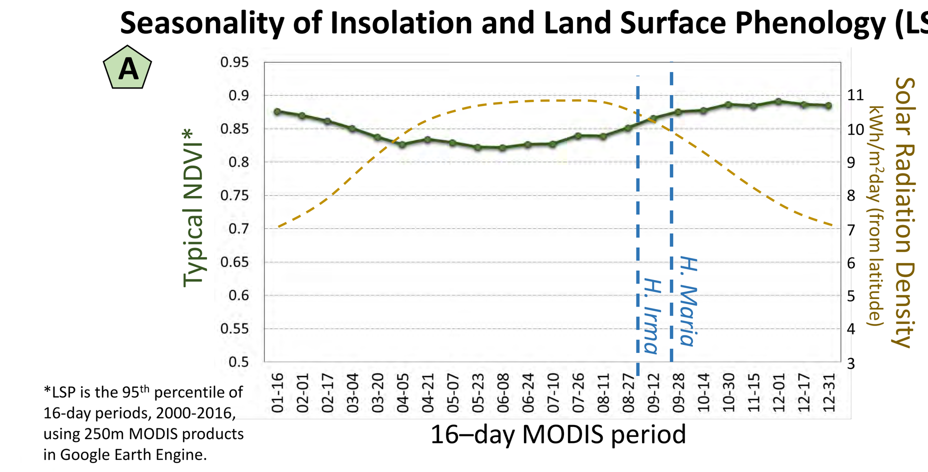
Remote sensing has a proven record of quantifying change from hurricanes using data from a variety of satellite platforms and indices, yet damage to humid tropical forests are relatively difficult to assess due to frequent cloud cover, high humidity and high vegetation productivity that includes rapid vegetative regrowth after disturbance. This study exploits newly available technology and datasets to overcome these historical challenges and to quantify hurricane damages to forests shortly after the event. We then assess the topographic factors that influenced the pattern of storm impacts.

METHODOLOGY

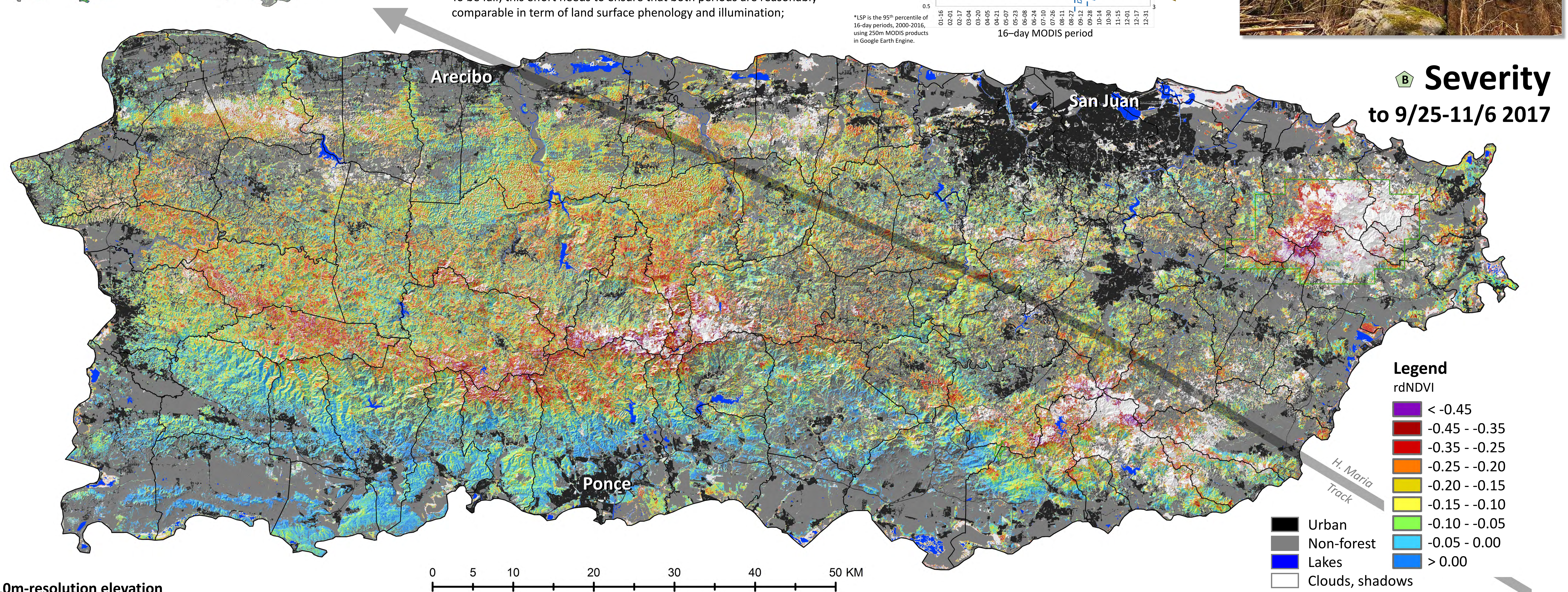
The most common method used to quantify vegetation change with remote sensing involves comparing pre- and post-disturbance states. To be fair, this effort needs to ensure that both periods are reasonably comparable in term of land surface phenology and illumination; this is challenging given the timing of the hurricane with respect to declining sun angles, seasonal greening and rapid sprouting. (A)

We used cloud computing with Google Earth Engine to isolate the best quality 10m Sentinel 2 NDVI values available for the post hurricane period through Nov. 6, after which time greening was deemed too be great to provide a consistent record of damage. We isolated clouds, cloud shadows and topographic shadows by thresholding Sentinel 2 bands 4 and 12. For the pre-storm period, we used the best Sep. 25-Dec. 31 date during 2015 and 2016, but we supplemented high quality full-year values where clouds or shadows were present for the Sep.-Dec. baseline. To measure severity, we calculated the relative difference vegetation index (rdNDVI), then generated 117,000 random points with a 50m minimum spacing, then extracted values from the data rasters to be compared.

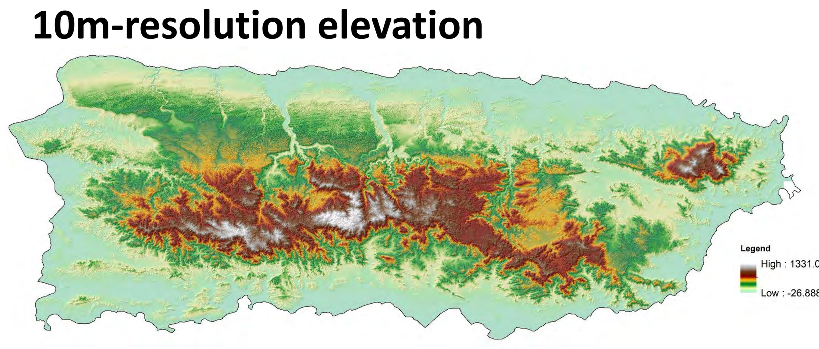
Seasonality of Insolation and Land Surface Phenology (LSP)



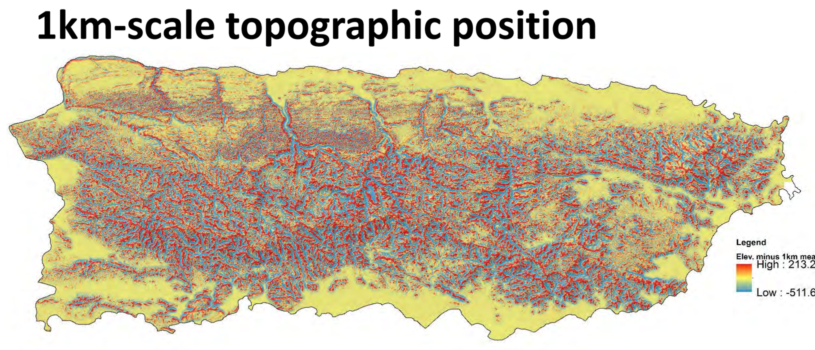
El Yunque National Forest. Credit: USFS



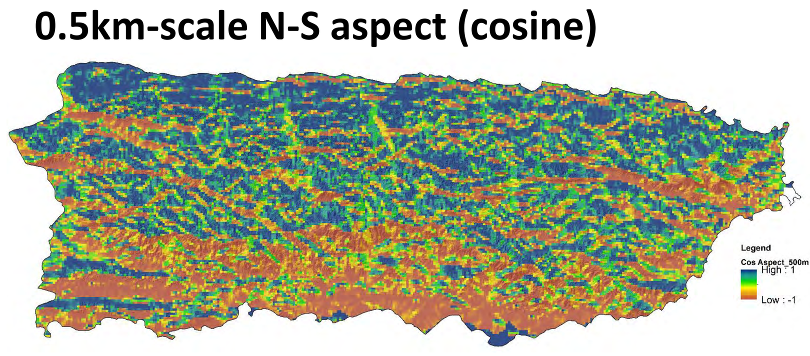
10m-resolution elevation



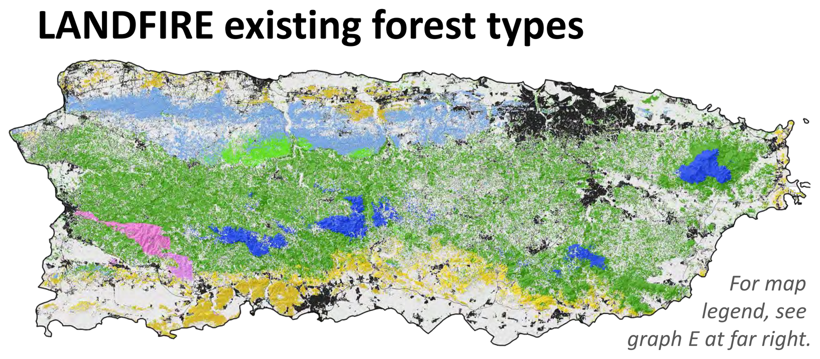
1km-scale topographic position



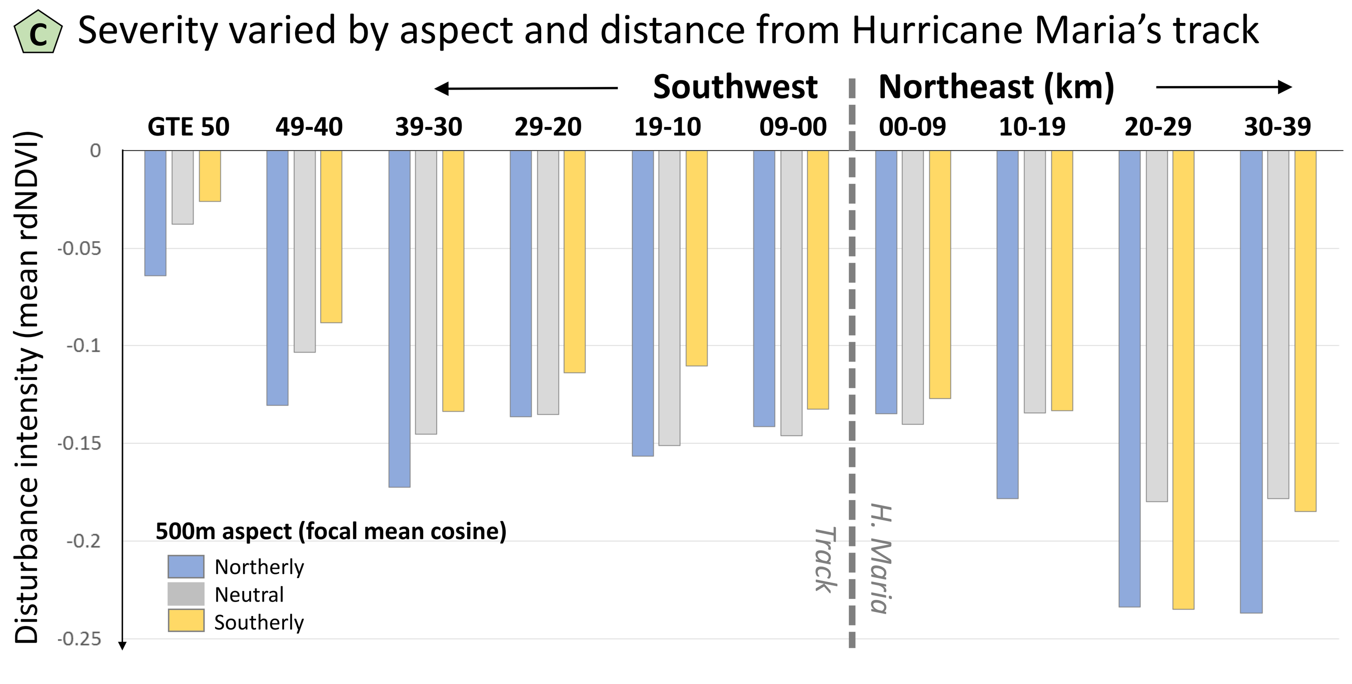
0.5km-scale N-S aspect (cosine)



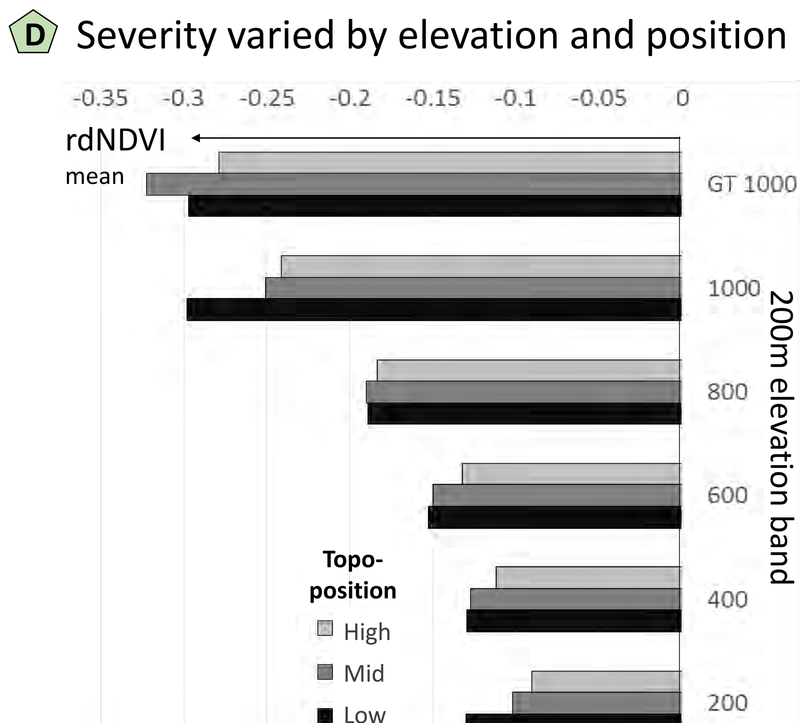
LANDFIRE existing forest types



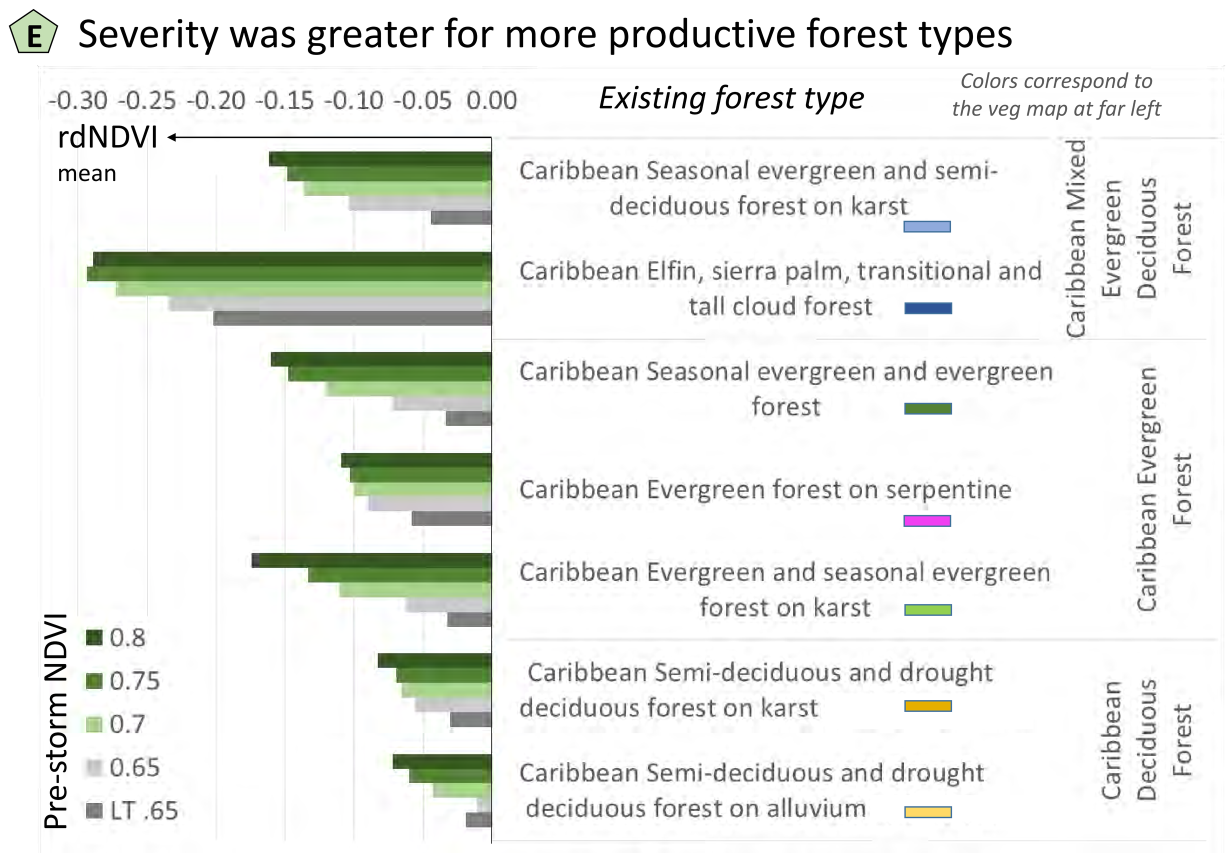
(C) Severity varied by aspect and distance from Hurricane Maria's track



(D) Severity varied by elevation and position



(E) Severity was greater for more productive forest types



RESULTS

Comparison of pre- and post-hurricane NDVI shows widespread and generally severe damage to forests. (B) Cloud cover obscured many of the productive, high elevation, forests that, where clouds were absent, showed extreme damage. Extending the post-hurricane window for more cloud-free dates was avoided due to rapid NDVI recovery.

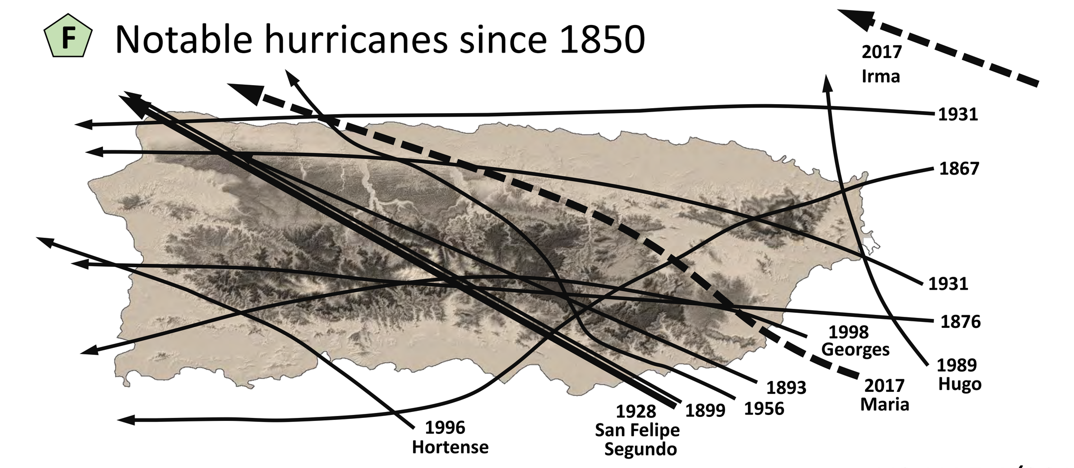
Forest impacts varied with broad and local scale gradients including distance from Hurricane Maria's track, the side of the storm (important given counterclockwise rotation) and N-S aspect. (C) Severity increased with elevation, but decreased somewhat with topographic position. (D) Change was greatest for high elevation mixed evergreen-deciduous forests, and least for drier deciduous forests, and the most productive sites within each mapped vegetation type, as measured by NDVI, showed the greatest severity. (E) The rdNDVI metric is designed to correct for the overly sensitive volatility of low NDVI sites as compared to higher sites.

CONCLUSIONS

Patterns of severity followed clear topographic gradients that would likely recur for future hurricanes, yet exposure, and much of the damage observed, also reflects contingencies of the event. For example, the extreme damage NE of the track may reflect the additional impacts of Hurricane Irma from two weeks earlier. (F)

Remarkably, the most productive vegetation experienced the most change, yet the high-NDVI forests of exposed, high elevation sites may also be most rapid to recover, given that environment. Perhaps of greater concern are the less productive forests that were also severely damaged, but slower to recover, especially if storms increase in frequency and/or intensity. Predictions of increased hurricane intensity for the Caribbean from climate warming suggest that the chance track positions of future storms may drive how this landscape continues to evolve.

(F) Notable hurricanes since 1850



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