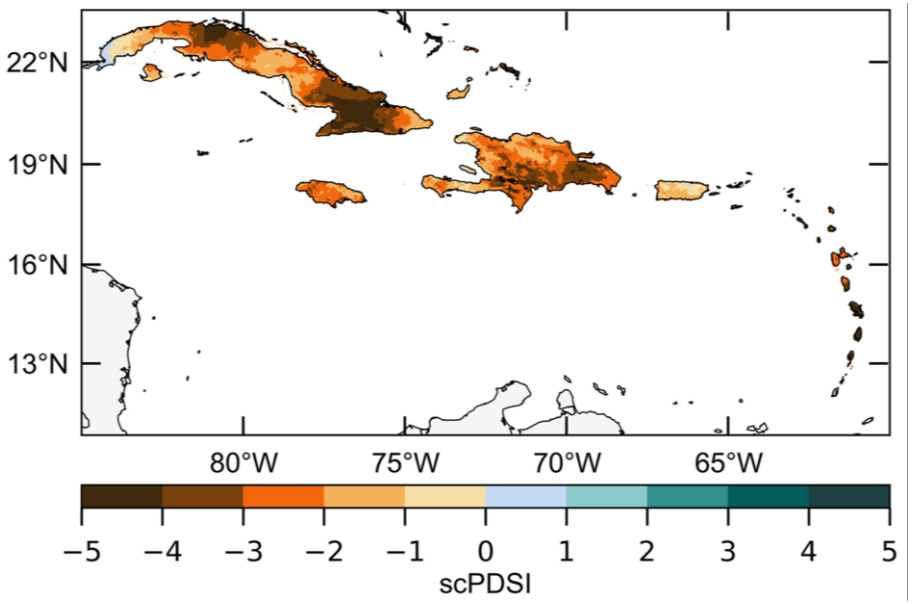
Drought Affects Mangrove Recovery Patterns Following Hurricane Irma

All photos, graphs, images created by researcher unless indicated otherwise

Motivation

- Mangroves buffer cyclone impacts as they resprout and recover rapidly
- This resilience can be compromised when compounded with drought
- Caribbean mangroves experiencing drought followed by Hurricane Irma in 2017 provided conditions to study recovery patterns of dually impacted areas
- Joint drought and cyclone impacts have **not** been investigated in mangroves



2013 – 2016 Caribbean Drought, Herrera et al., 2018

Mangrove Dieback After Irma, Lagomasino et al., 2021

Objectives

How did drought influence mangrove response and recovery to Hurricane Irma?

1. Quantify 2017 areal extent and benchmark against 2001 - 2016
2. Temporal dynamics
   - Determine onset of change within 2017 season
   - Differentiate between different types of damage
3. Recovery patterns
   - Does drought influence rate of recovery? How?
   - Will some types of areas never recover? What types?

Pre and Post Storm Mosaic

- Landsat 7 ETM+ and Landsat 8 OLI data
  - Pre-processed to surface reflectance and masked for clouds
  - Harmonized to account for differences in the sensor specifications
- Normalized Difference Vegetation Index (NDVI) calculated for each image
- Two reference maps (median mosaics) derived from time series

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

Mangrove Cover Classification

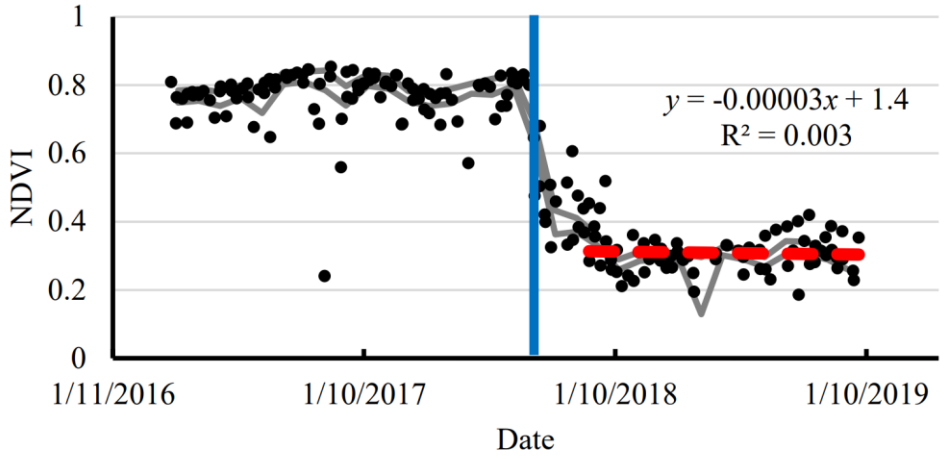
Landsat 8 Operational Land Imager imagery → Preprocessed to surface reflectance and clouds were masked → Selected training points → Normalized band ratios as model inputs → Random Forest Classification in GEE → External validation with QGIS

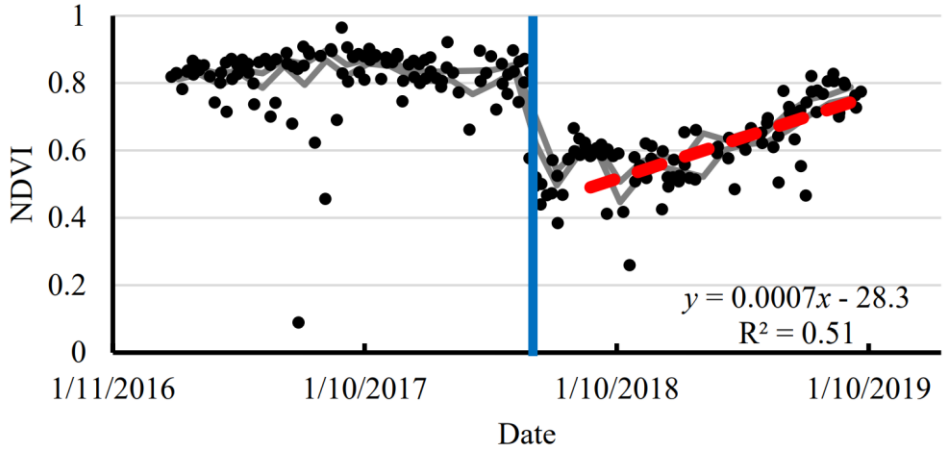
Damage

- NDVI anomaly - average change relative to pre-storm reference
- Threshold of 0.2
  - Suffered losses of canopy material
  - Coincident with lidar-derived canopy height change

Recovery

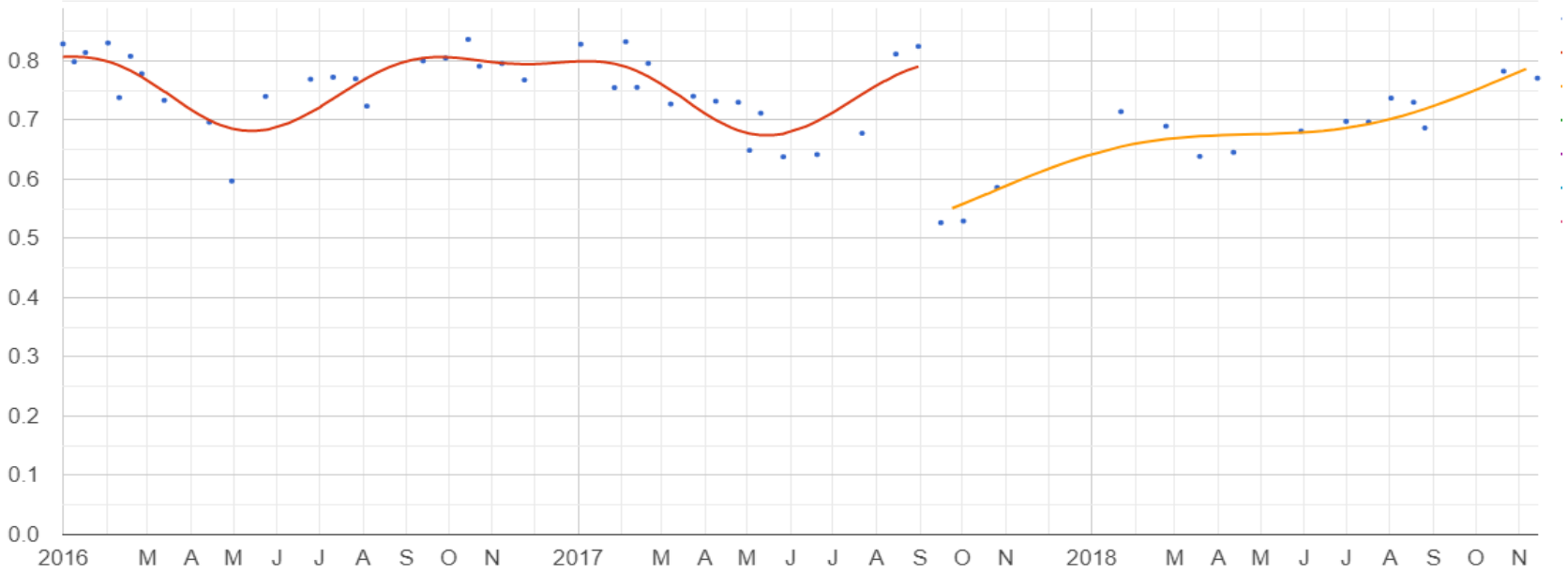
- Excluding data from October to December 2017





Time Series Modeling

- Modified continuous change detection algorithm
  - Determine timing and magnitude of NDVI changes as well as temporal distribution of dieback
- Processed dense Landsat image collection from 2016 – 2018
  - Removed observations affected by clouds, cloud shadows, and snow
  - Per-pixel Fourier series modeling and fitting with ordinary least squares (OLS) model
- Flagged change by differencing OLS predicted and observed index values



Additional Data and Analysis

Mangrove Drought History Index

- Developed Mangrove Drought History Index (MDHI) for damage analysis
- Three-year average mosaic of Palmer Drought Severity Index since 2001
- Severity calculated based on weighted drought class

Hurricane Storm Path

- GMAO modeled surface wind speed and categorized based on Saffir-Simpson

G-LiHT Airborne Lidar

- Mangrove canopy height map (Simard et al.)

Significance Test

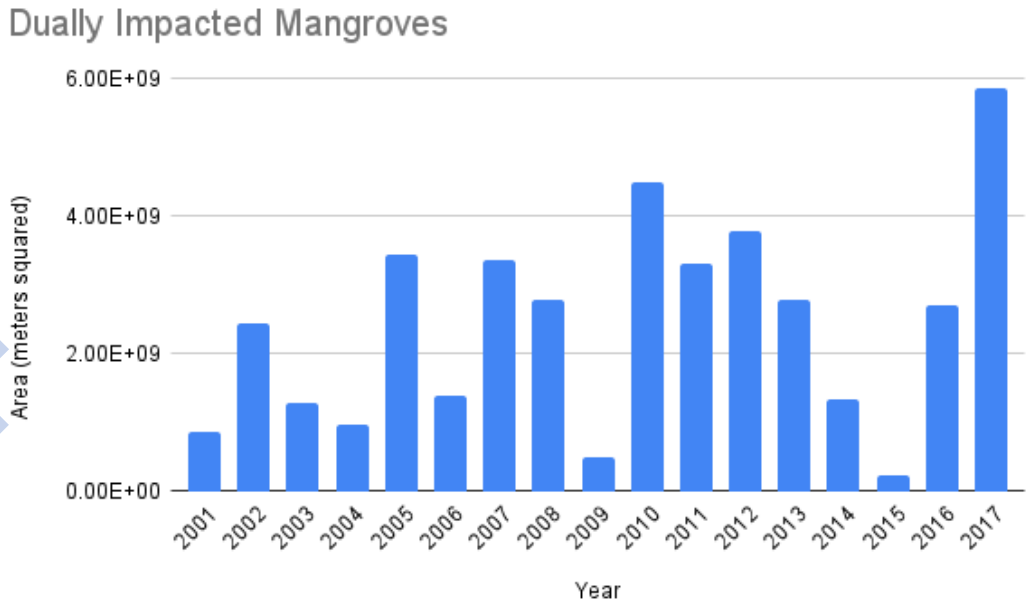
- Two-sided Kolmogorov-Smirnov

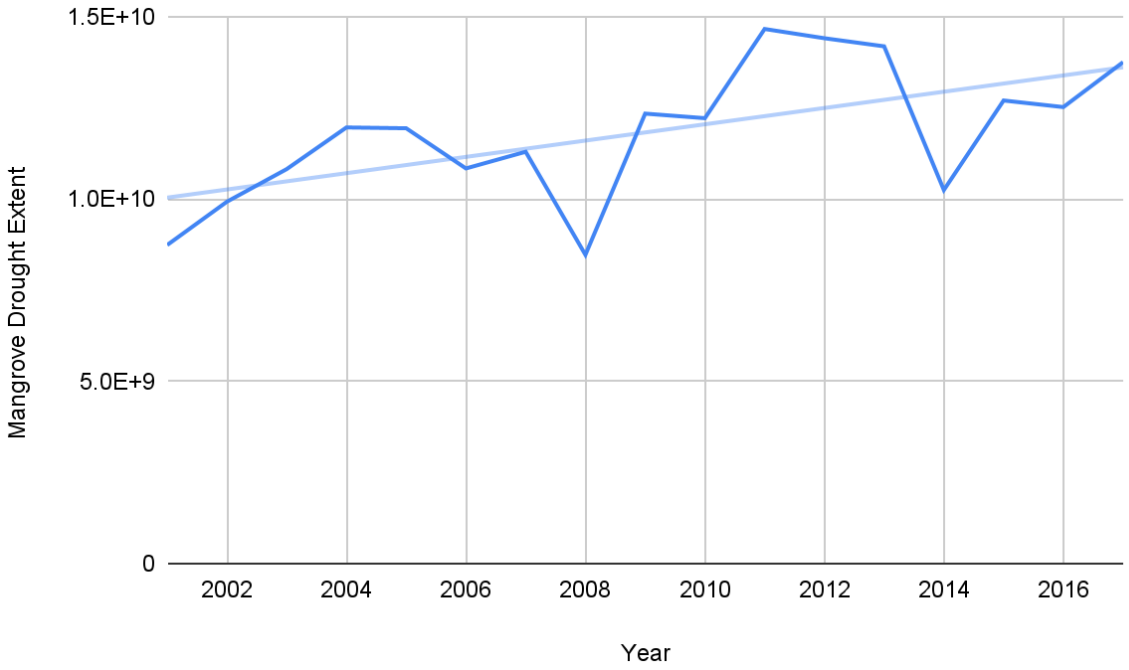
Results

Large-scale dual impact with extensive damage

- Unprecedented severe and widespread overlap
- Extreme mortality and over 1 million hectares of impact
- Drought has been significantly increasing since at least 2001

	Damage (hectares)
Overall	83,544.39
Storm	77,478.00
Drought	51,565.08
Dual Impact	48,534.98

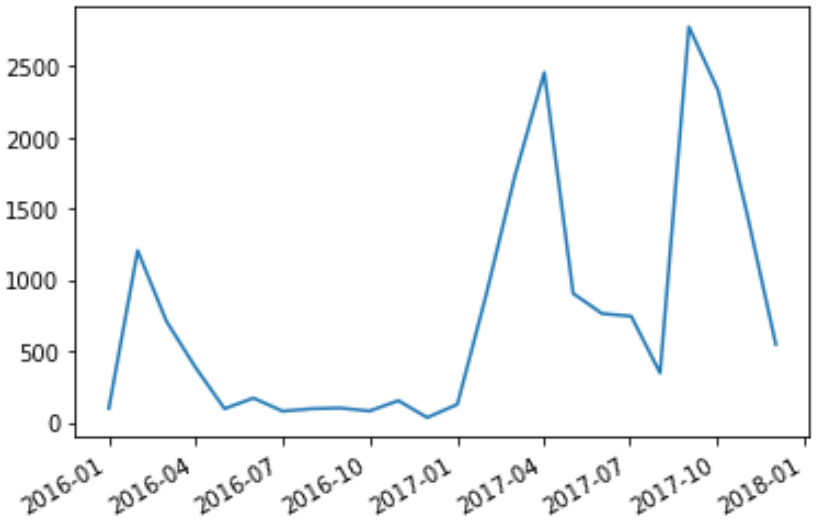


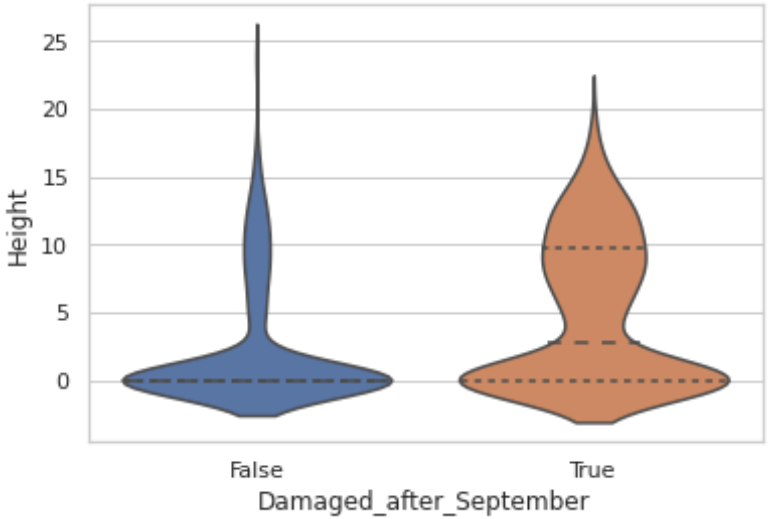


Results

Temporal patterns – **not all 2017 damage was due to Irma**

- Within the direct storm path - 6.8% of all damage occurred prior to Irma's landfall
- Outside of storm path - 52.85% of mangroves showed damage prior to Irma
- Previous studies attributed all 2017 damage to storms, but temporal analysis revealed two distinct groups of forest stands that experienced dieback
- Dieback due to Irma was taller and displayed larger canopy height variation

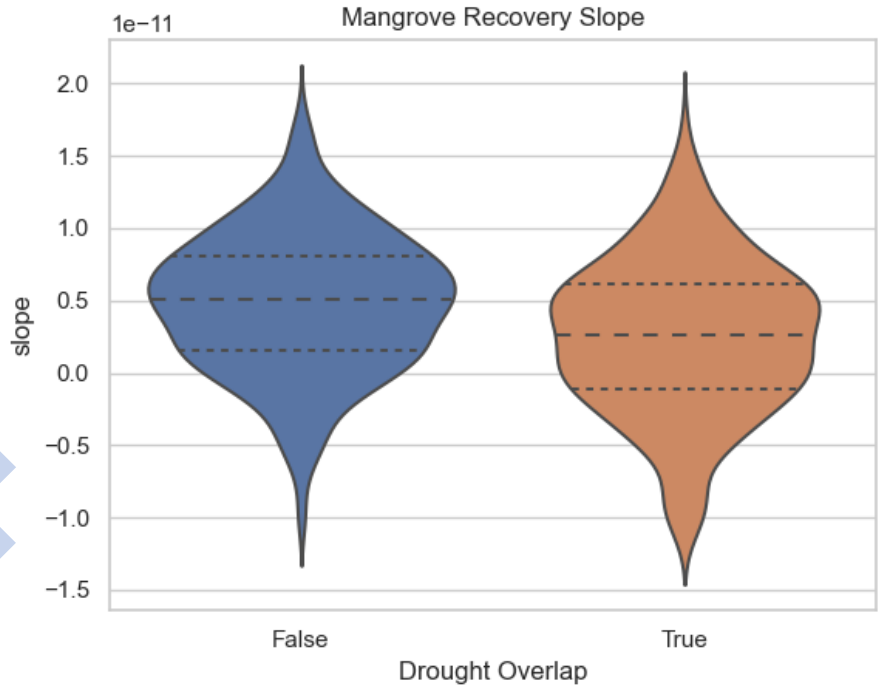


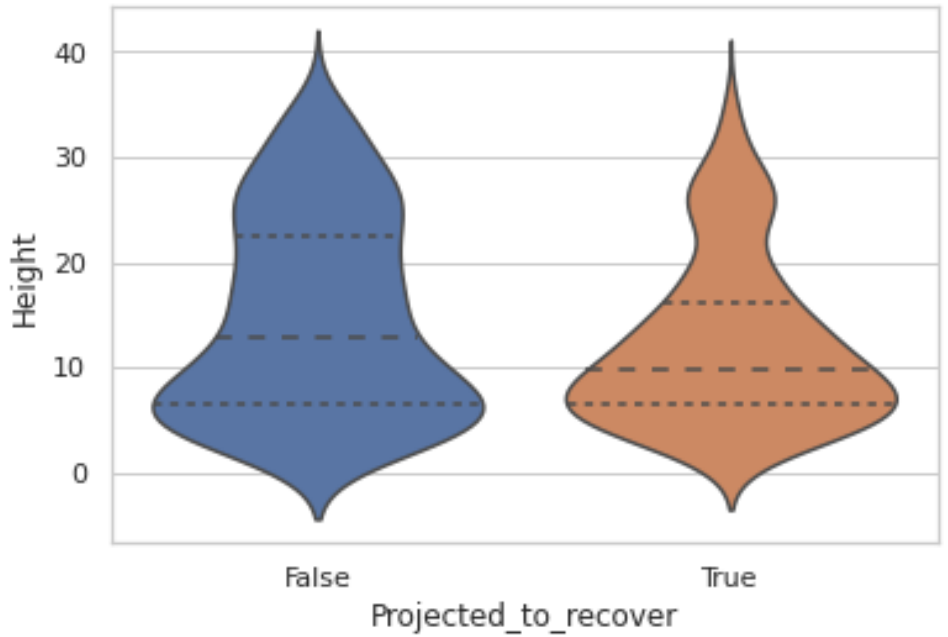


Results

Drought stress and height adversely impact recovery

- Storm areas not impacted by drought had better positive recovery trajectories
  - More positive recovery slope and shorter estimated time to return to pre-storm greenness
- Mangroves projected to recover tended to be shorter





Summary and Conclusions

- Assessed damages and impacts from Hurricane Irma and drought in 2017 and compared it to 2001 – 2016
- MDHI and NDVI anomaly index successfully quantified drought and dieback
- First ever time series modeling differentiated 2017 dieback into two groups

Drought adversely impacts mangrove recovery with **canopy height** influencing response

1. Remote sensing studies are critical to future ecosystem management
   i. We should target vulnerabilities in conservation (ex: tall trees under drought)
2. Temporal segmentation techniques are valuable for other disturbances
3. Drought history must be considered when assessing hydrological stress